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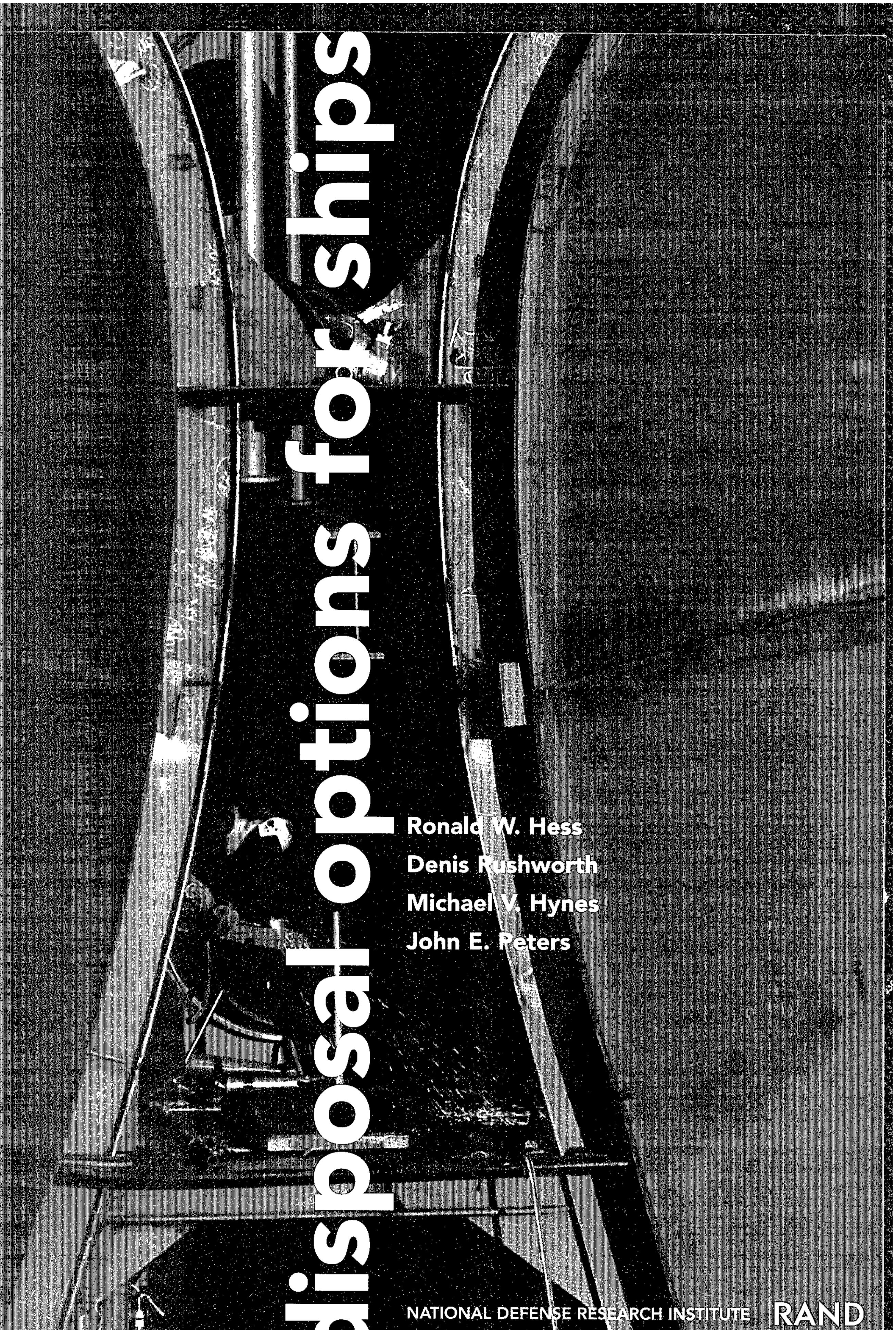

NATIONAL DEFENSE RESEARCH INSTITUTE RAND

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MR-1377-NAVY

Prepared for the United States Navy

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The research described in this report was conducted for the U.S. Navy within the Acquisition and Technology Policy Center of RAND's National Defense Research Institute, a federally funded research and development center supported by the Office of the Secretary of Defense, the Joint Staff, the Unified Commands, and the defense agencies under Contract DASW01-95-C-0059.

Library of Congress Cataloging-in-Publication Data

Disposal options for ships / Ron Hess ... [et al.].
p. cm.
MR-1377
Includes bibliographical references.
ISBN 0-8330-3014-0
1. Surplus government property—United States. 2. Ships—Scrapping—United States. 3. Ships—Storage—United States. 4. Artificial reefs—United States. I. Hess, Ronald Wayne, 1946–

VC263 .D57 2001
359.8'3—dc21

2001031894

Cover design by Eric Handel/LMNOP

Published 2001 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 102, Pittsburgh, PA 15213
RAND URL: http://www.rand.org/
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PREFACE

The objective of this study was to identify and evaluate options for the disposal of U.S. Navy and U.S. Maritime Administration (MARAD) ships. The research considered four options: long-term storage, domestic recycling, overseas recycling, and reefing (i.e., the sinking of ships to build artificial reefs). It also considered the use of private and public U.S. shipyards, international organizations, and partnerships between U.S. and foreign companies. Applicable environmental and worker health and safety regulations were taken into account in arriving at estimates of the costs, benefits, capacities, capabilities, feasibility, and risks associated with each option.

This research was conducted for the U.S. Navy within the Acquisition and Technology Policy Center of RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Commands, and the defense agencies.

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SUMMARY

The U.S. Navy and the U.S. Maritime Administration (MARAD) together preside over a fleet of some 450 retired naval vessels and merchant ships that grows each month as ship retirements continue. Some of these ships will find their way into the navies of U.S. allies and friendly nations, others will be sold or donated to interested parties, and some will be consumed in live-fire military exercises known as sinking exercises, or SINKEX. Those that remain, about 358 ships, will require some other form of disposal over the next 20 years. Those 358 ships were the focus of our study.

We evaluated four options for how the Navy and MARAD might proceed: long-term storage, domestic recycling (ship dismantlement in U.S. naval or commercial shipyards), overseas recycling, and "reefing"—i.e., the sinking of a ship(s) to create an artificial reef for a marine habitat or as a site for recreational divers. Of these four, only the last three are truly ship-disposal options. Long-term storage, which defers the decision of how to dispose of the ships until some later date, was included to show the consequences of taking no action.

APPROACH

The study's main thrust was to estimate the costs and offsetting revenues associated with each of the four options, to assess the stability or uncertainty associated with each factor, and to assess the associated risks and impediments. Because the U.S. Navy funds both Navy and MARAD inactive fleet expenses, we estimated total program costs. In some instances, we show the separate Navy and MARAD "shares" of the total costs. All costs are given in constant FY00 undiscounted dollars; total program costs are often also given in discounted net present value dollars.[1]

[1]A discount rate of 4.1 percent was used, per Office of Management and Budget, Circular A-94, at http://www.whitehouse.gov/OMB/ circulars/a094/a094.html.

Table S.1 summarizes the costs associated with the long-term storage option and the three disposal options; Figure S.1 shows the costs as a graph. The lower and upper ends of each floating bar in the figure represent the best-case and worst-case values, respectively. This range of values captures the full spectrum of possible outcomes in our cost model. The vertical stroke through each floating bar represents the baseline case, whose value captures the most reasonable expectation of option cost. With ship storage and title holdings as they now stand, the Navy will be responsible for about 45 percent of the cost of each option, with the balance falling to MARAD. Should the Navy transfer title to all eligible auxiliary and amphibious warfare ships to MARAD, the Navy share will fall to about 30 percent, with the balance going to MARAD. This variation is within the range between best and worst case shown.

Long-Term Storage

This option assumes that all 358 ships will be stored for 100 years and will still be in storage at the end of that period. This option is the most expensive of the four in terms of total costs over the 100-year period, amounting to $4.9 billion in undiscounted FY00 dollars, or $1.2 billion discounted. In terms of its impact on the near-term annual budget, long-term storage is competitive with the three disposal options, averaging $50 million per year.

Long-term storage is the course of action with the greatest amount of cost uncertainty. Our concerns about the accuracy of the estimated costs for this option focus on two cost factors:

- **Aging.** This factor represents how a ship's maintenance needs will grow as the ship ages. The cost model baseline uses a uniform aging factor of 0.5 percent per year to reflect the increase in maintenance cost. The expectation is that the older the ship becomes, the more maintenance it will need to stay afloat.
- **Interval between dry dock inspections.** The cost model baseline uses a uniform dry dock interval of 15 years for inspection and repair. If more frequent dry dockings were to become necessary, however—perhaps in response to greater-than-anticipated ship deterioration—costs could increase rapidly.

For our baseline, we used a 0.5 percent aging factor, a 15-year dry dock interval, and constant dry dock costs. The cost estimate for long-term storage in this case is $4.9 billion in undiscounted FY00 dollars. The best-case scenario involves no escalation in maintenance due to aging, a 20-year dry dock interval, and a constant dry dock cost. Under these conditions, the cost estimate is $3.8

Table S.1

Estimated Cost of Options

	Estimated Cost (millions of US$)			
Option	Worst Case	Baseline	Best Case	Baseline Average Annual Budget
Long-term storage				
Discounted	1,750	1,170	960	50 for 100-year program
Undiscounted	7,740	4,920	3,770	
Domestic recycling				
Discounted	2,590	1,370	510	94 for 20-year program
Undiscounted	3,600	1,870	680	
Overseas recycling				
Discounted	140	140	0	34 for 5-year program
Undiscounted	170	170	0	
Reefing				
Discounted	560	370	240	25 for 20-year program
Undiscounted	760	500	320	

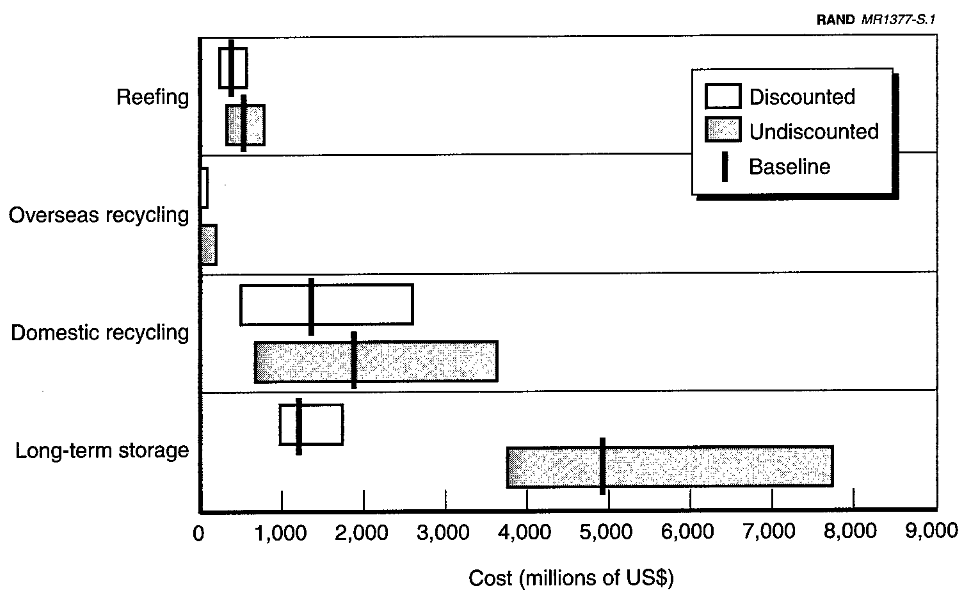

Figure S.1—Estimated Cost of Options

billion in undiscounted FY00 dollars. The worst-case scenario involves a 1 percent cost increase due to aging, a 10-year dry dock interval, and a 25 percent higher dry dock cost. Under these conditions, the cost estimate is $7.7 billion in undiscounted FY00 dollars.

Long-term storage is not truly an option for the problem of ship disposal. It only defers the problem for another generation. In other words, whether stored for 20, 50, or 100 years, the 358 ships would still have to be dealt with in the end. For this reason, we concluded that long-term storage is not a viable course of action and not a sound policy.

Domestic Recycling

This option proved difficult to estimate accurately because of the labor-cost uncertainties likely to attend ship dismantling in the United States. We used the best data available from Puget Sound Naval Shipyard (PSNS), the Navy's Ship Disposal Program (SDP) contractors, and other sources. The complexity of the dismantling process for the various ship classes is another source of uncertainty. We developed a relationship between light ship weight (LSW) and the dismantling cost based on all the available data. We then used this relationship and other cost factors (such as towing, interim storage, and learning curve efficiencies) to arrive at baseline, best-case, and worst-case cost estimates. The available data on the cost to recycle specific ships at specific ship recyclers vary widely, so we caution against using our estimating approach for any specific ship. Of the variables contributing to the overall cost estimate for this option, the learning curve and the dismantling costs have notable influence while the value of scrap metal has little.

The baseline scenario for this option entails a 95 percent learning curve, the best-fit value for labor costs and ship complexity, and the October 2000 scrap prices. The result is a baseline cost estimate of $1.9 billion in undiscounted FY00 dollars, or about $1.4 billion in discounted dollars. The 95 percent learning curve we used is what was experienced by PSNS during its submarine recycling program. This learning curve, which is typical for heavy industry engaged in low-rate repetitive tasks, means that the last ship in a 20-year program will cost about 72 percent of the first. A learning curve beyond 95 percent for heavy industrial work of the kind involved in ship recycling would be difficult to achieve, as evidenced by PSNS experience.

Our best-case scenario for this option entails a 90 percent learning curve, the lower end of the labor cost error band based on the PSNS and SDP data (30 percent less than the baseline rate of $863 per ton of LSW), the lower end of the ship complexity error band (16 percent less the baseline case), and a 50 percent increase in scrap value. Under these conditions, the estimated best-case cost

for domestic recycling is $680 million in undiscounted FY00 dollars. Our worst case involves a flat learning curve, the upper end of the PSNS and SDP labor costs (30 percent above the baseline rate), the upper end of the complexity error band (16 percent above the baseline), and a 50 percent decrease in scrap value. Under these conditions, the estimate for domestic recycling is $3.6 billion in undiscounted FY00 dollars.

Overseas Recycling

Virtually all present-day recycling of merchant ships and warships is done overseas in four Asian countries: India, Pakistan, Bangladesh, and the People's Republic of China. Turkey is the only European country that has a notable ship recycling industry. At one time, overseas recycling was a major means of disposal for Navy and MARAD ships.

The basic business model for overseas ship recycling is as follows: The ship owner or broker delivers a ship to the recycling site and in return receives payment based on the ship's LSW, the prevailing cost for recycling labor and materials, and the anticipated revenues for scrap metal and reusable equipment. Most merchant ships sail under their own power to the recycling site, but all or nearly all of the 358 ships in the Navy and MARAD inventory are or will be inactive and thus must be towed. For all 358 ships, the towing cost will exceed the ship's value in the overseas recycling markets, although some combination of markets and judicious choice of towing arrangements may produce a small amount of revenue for the U.S. government. The cost for overseas recycling of all 358 vessels assuming suboptimum choices for towing arrangements and including the cost of storing the ship during the notional five-year duration of such a program would be no higher than $170 million in undiscounted dollars. Such a program may cost nothing if towing costs can be optimized. However, overseas recycling activities have been subject to great uncertainty because of short-term economic pressures and long-term environmental and safety pressures. Established industries in India and Turkey appear to be in decline because of these pressures. Moreover, U.S. regulations regarding the export of polychlorinated biphenyls (PCBs) will have to be amended before the United States can resume exporting ships containing residues of this pollutant.

Discussions under way within three United Nations (UN) organizations—the International Maritime Organization (IMO), the UN Environmental Program, and the Basel Convention on the Transboundary Movement of Hazardous Wastes—may lead to a new regulatory regimen for the ship recycling industry that could radically alter the nature of the international maritime industry. Because of all these uncertainties, we recommend that the Navy and MARAD not pursue the overseas recycling option despite its attractive cost.

Reefing

Reefing is a very promising ship disposal option. There is a history of success in using sunken ships to build reefs that benefit marine life, commercial and sport fishing, and recreational diving. Reefing is also one of the least expensive disposal options. The baseline case cost estimate for a 20-year program to dispose of the current inventory of 358 ships through reefing, including towing and interim storage, is $500 million in undiscounted FY00 dollars. Offsetting government tax revenues can be expected from the business activity associated with the new reefs. Calculations using optimistic estimates show that the accumulated tax revenues will equal the cost of the program by its twelfth year.

Compared to the overall cost of the domestic recycling option, that of the reefing option is less sensitive to variations in learning curve and ship preparation costs. This is because the costs of towing and interim storage, which are fixed costs, make up a greater fraction of the total cost in reefing than they do in domestic recycling. To estimate the cost of the reefing option, we analyzed the cost data available from previous reefing projects and obtained estimates from Navy shipyards and commercial groups. The data lie on a remarkably uniform trend line, which allowed us to do a high-confidence evaluation of program cost versus ship complexity.

The baseline for the reefing option assumes a 95 percent learning curve and the best fit values for the labor costs and complexity factors. The cost estimate in this case is $500 million in undiscounted FY00 dollars. The best-case cost scenario entails a 90 percent learning curve, the lower end of the labor cost error band (±30 percent), and the lower end of the complexity error band (±16 percent). The result is $320 million in undiscounted FY00 dollars. The worst case entails a flat learning curve and the upper end of both the labor cost and the complexity error bands. For this case the estimate is $760 million in undiscounted FY00 dollars.

The biggest unknown associated with reefing is the standard to be used for preparing ships for reefing. Most reefing projects thus far have employed local, U.S. Coast Guard, or Canadian standards in cleaning and preparing ships for sinking. A sound long-term reefing program requires new national standards for ship cleaning and a coordinated Navy-MARAD interagency program.

RECOMMENDATIONS

To reduce the current risk of ship sinking or other notable environmental damage, the Navy and MARAD should exploit the experience gained in the Navy's ongoing Ship Disposal Program and the recently initiated MARAD program to dispose of poor-condition ships in the inventory. At the same time, both agen-

cies should initiate coordinated discussions with the Environmental Protection Agency (EPA) and other coastal regulatory authorities to develop standards for reefing that will make it a viable, long-term option for disposing of as many of the 358 ships as possible. The goal should be to dispose of the current inactive fleet by 2020 or earlier, since that time frame will have only a modest impact on the Navy and MARAD budgets and is well within the capabilities of the available industrial base. The Navy and MARAD should not opt for overseas recycling; such a program would involve many impediments and difficulties. Neither should they opt for long-term storage. This option entails high and uncertain costs and only defers, rather than solves, the problem of disposing of the 358 ships.

ACKNOWLEDGMENTS

We would like to thank Commander Charles Behrle, USN, and Eugene Magee, of MARAD, for their help and support throughout the course of this project. Their aid in gathering critical data and providing access to important information was invaluable, and their comments on and insights into issues attending the inactive fleets, ship disposal, and similar matters enriched the project considerably.

We also want to acknowledge the staff and members of the Atlantic States Marine Fisheries Commission and the Gulf States Marine Fisheries Commission, particularly Mel Bell of South Carolina and Tom Maher of Florida; Dick Long of the San Diego Oceans Foundation; Jay Straith of the Artificial Reef Society of British Columbia; the National Steel and Shipbuilding Company; and the U.S. Coast Guard in the person of Nick Petagno and his teammates. All of these made notable contributions to our understanding of the reefing option.

We thank all of the many employees of the Puget Sound Naval Shipyard who informed the basis of our domestic recycling option, as well as those of Baltimore Marine Industries and Metro Machine Incorporated who did the same. We also thank Naresh Maniar, who diligently and successfully informed us about ship recycling in Asia, and Unal Bener, who did the same concerning Turkey. To those at Crowley Marine of Seattle who provided us with invaluable information on the cost of ship towing, and those of NAVSEA PMS 333 who contributed in many different areas, we also express our thanks.

We also would like to express our deep appreciation for the formidable contributions of our team leader, Ron Hess, whose untimely death near the project's end was a loss deeply felt by all.

ACRONYMS AND ABBREVIATIONS

ABS	American Bureau of Shipping
AMP	amphibious warfare
ARK	Artificial Reefs for the Keys
ARSBC	Artificial Reef Society of British Columbia
ASMFC	Atlantic States Marine Fisheries Commission
AUX	auxiliary
BB	battleship
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
CG	cruiser
CP	cathodic protection
CRB	Commodity Research Bureau
CV	aircraft carrier
DDG	destroyer, guided missile
DH	dehumidifying
DoD	Department of Defense
EPA	Environmental Protection Agency
F&W	Fish and Wildlife
FF	fast frigate
FFG	fast frigate guided missile
FMS	foreign military sales
FOB	freight on board
GNP	gross national product

GRT	gross registered tons
GSMFC	Gulf States Marine Fisheries Commission
HMAS	Her Majesty's Australian Ship
HMCS	Her Majesty's Canadian Ship
IMO	International Maritime Organization
JRRF	James River Reserve Fleet
LSW	light ship weight
LT	long ton
MARAD	Maritime Administration
MCMV	mine countermeasure vessel
MOB	mobilization
NASSCO	National Steel and Shipbuilding Company
NAVSEA	Naval Sea Systems Command
NISMF	Naval Inactive Ship Maintenance Facility
NOAA	National Oceanic and Atmospheric Administration
NVR	Naval Vessel Register
OECD	Organization for Economic Cooperation and Development
PADI	Professional Association of Diving Instructors
PCB	polychlorinated biphenyls
PL	Public Law
PMS 333	NAVSEA organization that manages the inactive fleet
POP	persistent organic pollutant
PSNS	Puget Sound Naval Shipyard
PVC	polyvinyl chloride
RF	Reserve Fleet
ROM	Rough order of magnitude
RR	Ready Reserve
RRF	Reserve and Retired Fleet
SCUBA	self-contained underwater breathing apparatus
SDOF	San Diego Oceans Foundation
SDP	Ship Disposal Program

SINKEX	sinking exercise (naval target practice)
UN	United Nations
UNEP	UN Environmental Program
USCG	U.S. Coast Guard
USGPO	U.S. Government Printing Office
USS	United States Ship
VAT	value added tax
VSTOL	vertical short takeoff and landing

Chapter One

INTRODUCTION

The U.S. Navy and the U.S. Maritime Administration (MARAD)[1] together oversee an aging fleet of inactive military and merchant ships that increase in number each year and must be disposed of. Some of these ships end up in museums (about 51 now serve as museum exhibits); others become the subject of foreign or domestic donations, sales, or leases. The remainder of this inactive fleet, as of November 2000 and considering those ships to be added through the year 2005, comprises about 358 ships, all of which have to be disposed of by other means.

We have assumed for this study that additions to the Navy and MARAD inactive fleet beyond 2005 will equal subtractions via sales, sinking exercises, and donations. For the Navy, these three disposal means have recently averaged about 30 ships per year as the fleet has been downsized.[2] The DoD is envisioning a Navy fleet of about 300 ships in the future, and the building rate and corresponding ship retirement rate to sustain such a fleet is about 10 ships per year, well within the figure of 30 ships per year.[3] For MARAD, the picture is not as clear; it depends on future decisions regarding the size of the reserve fleet designated for "indefinite retention." Should this fleet be downsized faster than can be accommodated by sales or transfers, the 358-ship figure will grow. Figure 1.1 summarizes the numbers and types of ships in the Navy and MARAD inactive fleet. Appendix A provides a comprehensive list of ships and explains how the inventory of 358 ships was developed.

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[1]MARAD is the U.S. government's disposal agent for merchant-type vessels of 1,500 gross tons or more. This currently includes Navy noncombatant ships, which have come to be loosely interpreted as Navy merchant-type ships. The Department of Defense (DoD) must dispose of all combatants itself.

[2]See Chapter Three, Table 3.1, for a summary of Navy ship disposals since 1974.

[3]Letter from U.S. Secretary of Defense to Senate Armed Services Committee, "Department of Defense's Naval Vessel Force Structure Requirements," June 26, 2000.

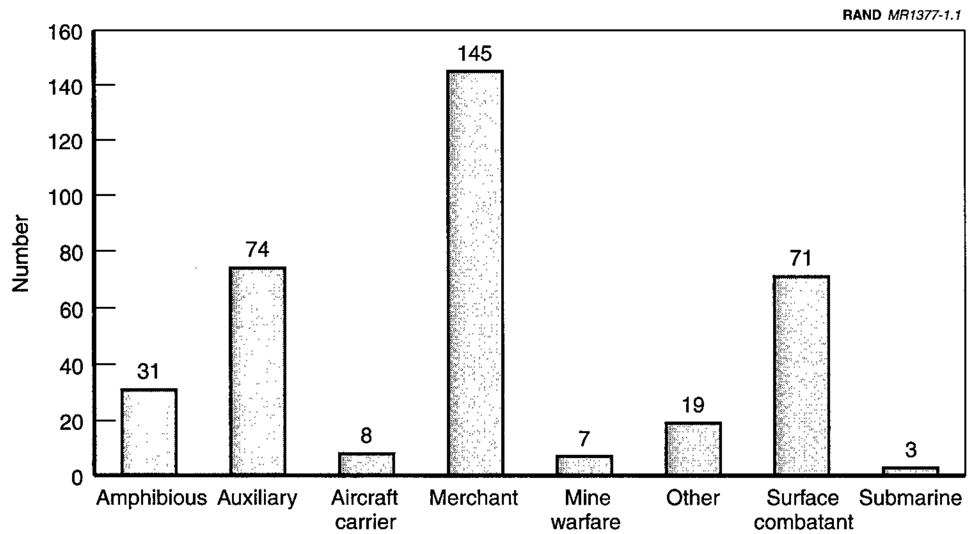

Figure 1.1—Number and Type of Navy and MARAD Ships Awaiting Disposal

At issue is the appropriate course of action for disposal of these ships. They might be maintained in indefinite long-term storage, they might be recycled[4] in a U.S. Navy or commercial shipyard, they might be recycled overseas, or they might be reefed—i.e., sunk at carefully selected coastal sites to provide artificial reefs as habitat for marine life or attractive destinations for recreational divers.

Various concerns attend these four options, however. Long-term storage raises fears of accidental sinking through hull corrosion or severe storms or environmental damage from spills or leaks. Maintenance costs are also a factor in long-term storage, especially if mounting corrosion problems or environmental incidents prompt more frequent or more extensive maintenance. And, of course, long-term storage does not actually dispose of the ships—it only delays the problem of disposal until some future time. As for recycling, it raises cost-efficiency concerns when dismantling is to take place in U.S. yards, environmental impact and worker safety concerns when recycling is done either in the United States or overseas, and issues of international traffic in and export of highly controlled waste materials when done overseas. Like recycling, reefing raises questions about necessary environmental protections.

Our study entailed assessing the four courses of action just outlined. The first chapter describes the disposal problem and the fleet of ships awaiting disposal.

[4]Many texts refer to ship recycling as "shipbreaking" or "ship scrapping." We use the term *recycling* because it more accurately conveys that most of the materials in a ship are reused in some way.

Chapters Two through Five deal, respectively, with long-term storage, domestic recycling, overseas recycling, and reefing. We considered the use of ships for military target practice, called *sinking exercises*, or *SINKEX*, only as a way to dispose of Navy ships entering the inactive fleet after 2005, when retirements to the fleet could be accommodated by SINKEX, sales, and donations. Chapter Six provides a comparative analysis of all four options and concludes with recommendations.

Because the Navy funds both Navy and MARAD inactive fleet expenses, we have for the most part estimated only total program costs. In a few instances, we provide both the Navy and the MARAD "share" of the total costs as information for those in each agency who are responsible for administering inactive ship programs. We express all costs in constant FY00 undiscounted dollars, in many instances also giving the discounted net present value for total program costs.[5]

ORIGINS OF THE INACTIVE FLEET

Upon the Secretary of the Navy's decision that a ship is no longer needed in active service, the ship is inspected by the Navy's Board of Inspection and Survey to determine whether it is still physically fit for service. A fit ship may be offered for lease to a foreign government, inactivated and placed in the inactive fleet for future mobilization, or declared excess and stricken from the U.S. Naval Vessel Register (NVR). An unfit ship is also stricken from the NVR, but then it is either offered for foreign military sale (FMS) to governments that wish to restore it to service, retained as a source of spare parts for operating ships of its class, or otherwise disposed of. MARAD maintains the Ready Reserve (RR), a fleet of merchant ships ready to carry military cargo in times of national emergency. When these ships are no longer serviceable, they are added to the inventory of unfit ships awaiting disposal. Occasionally, a few ships from sources such as the U.S. Coast Guard also find their way to the inactive fleet where they await disposal.

Ships awaiting final disposal are held at one of the Navy's four Naval Inactive Ship Maintenance Facilities (NISMFs) or at one of three MARAD inactive ship facilities pending completion of disposal arrangements. Stricken Navy ships determined to be merchant or merchant-type ships or capable of being converted to merchant use are transferred to MARAD for final disposal; warships are disposed of by offices of the DoD. In the 1960s and 1970s the U.S. government sold hundreds of ships from the Navy and MARAD inactive fleets for scrap both domestically and internationally, relying on the private sector to perform

[5]A discount rate of 4.1 percent was used, per Office of Management and Budget Circular A-94, available at http://www.whitehouse.gov/OMB/ circulars/a094/a094.html.

the work. In the 1980s the number of ships stricken declined because of the Reagan-era naval buildup. In 1991 the Navy, through such government agencies as the Defense Logistics Agency, resumed ship recycling to deal with the influx of ships to the inactive fleet that resulted from the post–Cold War military downsizing.

However, between 1970 and 1990 a fundamental change in the world's ship recycling industry took place: the industry, which now recycles about 700 ships per year, migrated from the United States, Spain, Portugal, and Italy to India, Pakistan, China, the Philippines, and Bangladesh, where labor is cheap and environmental restrictions are minimal. The U.S. recycling industry generally contends that it is now more difficult to recycle ships and to make a profit because U.S. environmental laws and worker health and safety laws have become more protective. Additionally, U.S. scrap metal prices are currently significantly lower than those on the Indian subcontinent, and the supply of ships to be recycled in the United States is small and unstable. As a result, between 1991 and 1997, only 34 Navy and MARAD ships were recycled domestically, down from a total of approximately 980 ships between 1970 and 1982. Twenty ships sold for U.S. recycling had to be recovered by the Navy because of contractor default.

Concerns About Navy Recycling

In 1997 members of Congress and some environmental groups raised concerns about Navy ship recycling that focused on U.S. environmental, health, and safety violations and poor overseas environmental, health, and safety conditions at recycling sites.[6] On December 9, 1997, the Secretary of the Navy suspended any efforts to sell U.S. Navy ships overseas for recycling. Concerns about safety and health at overseas recycling yards are not limited to U.S. interests, however. International civilian shipping and environmental communities have shown growing concern about the conditions in overseas yards, and international environmental regimes such as the Basel Convention on Hazardous Wastes have made efforts to regulate overseas recycling.[7]

Overseas recycling has now effectively become unavailable to the Navy and MARAD. As a result, some 252 ships of Navy origin, about 99 ships of MARAD origin, and seven ships originating from other agencies await recycling in Navy and MARAD facilities. Detailed information on this inventory of 358 ships is

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[6] *Report of the Interagency Panel on Ship Scrapping*, USGPO, Washington, DC, April 1998.

[7] *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal*, UN Environment Programme (UNEP), 1989, at http://www.unep.ch/basel.

provided in Appendix A, Table A.2.[8] These 358 ships cumulatively represent a backlog of approximately 2,772,000 light ship weight (LSW) tons.[9]

The backlog of ships poses several problems. There are increased environmental risks associated with an aging, inactive fleet; there is the ever-present potential for ships to sink at their anchorages. Some incidents of discharged hazardous materials have already occurred, and the potential for more may grow as the ships age. Maintenance costs also increase as ships age. And the inevitable need to shuffle ships among available facilities to meet emerging needs adds further to the expense.

The use of ships to build artificial reefs, a largely unexplored way to reduce the backlog, has been encumbered in part by the recent discovery of residues of polychlorinated biphenyls (PCBs) in many shipboard materials for which there are few clear management rules. Consequently, the Navy is concerned about the long-term liability attached to reefed ships.

The backlog may be helped by the Navy's having recently obtained EPA concurrence to expend a few ships each year for SINKEX. These exercises provide valuable training to fleet units as well as useful opportunities to test ship and weapons system designs. We assumed that SINKEX plus occasional donations and FMS would keep the inventory from growing above 358 ships beyond 2005.

Environmental and Worker Safety Considerations

Some of the environmental considerations about ship disposal are very obvious (spills and leaks) while others are less so. Ships often contain many fuels, oils, solvents, refrigerants, halons, and chlorofluorocarbons (CFCs) necessary for their operating systems. In older ships, electrical transformers and many nonmetallic materials often contain PCBs, and most such ships are insulated with asbestos. Lead-based paint that may also contain PCBs covers many of the steel surfaces. These materials present both environmental and worker safety hazards. For example, lead-based paint chips are a toxic waste in the environment, but lead-based paint also poses a potential health risk to any worker who in attempting to burn the paint off steel being recycled accidentally inhales the resulting fumes. PCBs and asbestos pose safe-handling and health problems for

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[8] Table A.2 is not intended as a specific list of ships but as a tool accounting for ship leases, donations, sales, and SINKEX that we can use to arrive at an approximate number and tonnage of ships for our analyses.

[9] In January 2001, just as this report was being finalized, we were advised that 17 of the 358 ships were disposed of by recycling, transfer to the General Services Administration for sale, or some other means. Nearly all were small ships and vessels amounting to no more than 1 percent of the total LSW in the working inventory. These recent changes thus have a negligible impact on our cost estimates.

workers who must remove these substances from ships during the dismantling process—especially overseas, where safety equipment is often minimal. U.S. export of PCBs is presently strictly prohibited, which severely restricts the exporting of ships for recycling because most of them contain PCB residues. Finally, some officials have expressed concerns about the appropriateness of exporting ships that may contain hazardous materials to developing countries. Indeed, since 1992, 130 countries have embraced the Basel Convention, which (among other things) allows export of hazardous wastes only under carefully specified conditions with full disclosure between the parties to the transfer and only among countries that are party to the convention. Whether ships destined for recycling are hazardous wastes under the terms of the Basel Convention remains an unsettled issue, as does the ultimate impact of any such determination and the attendant regulations on the world's merchant marine industry.

Cost-Effectiveness

The volatility of prices for scrap metal[10] and other by-products of ship recycling, variations in labor costs, and the differing environmental, safety, and health rules make cost-effectiveness a notable issue. Compared to their U.S. counterparts, overseas firms, especially those that dismantle ships on beaches, enjoy huge advantages in terms of low wage scales, low overhead costs, and high scrap prices. The calculus becomes more complicated, however, if cost-effectiveness must also take into account workers killed and maimed in the ship recycling business, or the environmental and public health consequences arising from improper disposal of large quantities of hazardous materials.

EVALUATING THE OPTIONS

The cost model built for this study is described in detail in Appendix E. We used it in estimating the net costs associated with each of the four options.

In the following chapters, the baseline estimates given for the four options each represent a point estimate produced by the cost model from inputs accurately representing the cost and revenue factors prevailing at the time. However, many of these factors (e.g., scrap resale prices) are subject to substantial and sometimes sudden variation that could invalidate a point estimate. We sometimes had very limited data sets to work with, and we did not want to generalize from them in mathematically unsound ways. The cost estimates for the options thus reflect these circumstances. We concluded that given the limitations, un-

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[10]Appendix D provides information on the volatility and regional variation of the U.S. scrap metal market.

certainty, and volatility attending some of the cost and revenue factors, the best way to represent the costs of the individual options was as a range. Each cost estimate thus is represented graphically as a wide bar, with the best-case cost and revenue factors defining the lower boundary of the estimate and the worst-case cost and revenue factors defining the upper boundary. We concluded that such a presentation—a range of costs with the baseline cost highlighted within it—was the best way to establish a robust estimate for each option.

Chapter Two

LONG-TERM STORAGE

Long-term storage has played a substantial role in the Navy-MARAD approach to managing their fleet of inactive ships and has by default become the primary management tool in recent years. This chapter examines the costs of maintaining the inactive fleet of 358 ships in storage for 100 years and the environmental concerns that might undermine long-term storage as an option. Of course, long-term storage is not actually a disposal option, since it only defers disposal. But it does represent the consequences of not taking some other action to dispose of the 358 ships.

We selected a duration of 100 years to highlight the fact that the Navy and MARAD must treat long-term storage as a deliberate decision that will bring with it costs beyond those that either is encountering with their current storage of ships awaiting disposal. To remain safely and securely afloat for 100 years, the ships will have to be protected within and without from corrosion attack with cathodic protection (CP) systems, dehumidifying (DH) systems, periodic dry dockings for inspections, hull preservation, and repairs. Most of the 358 ships are not presently maintained in this manner. All of this costs money.

THE COSTS OF PRESERVATION MAINTENANCE

Preservation costs for ships in long-term storage comprise the direct labor and material costs for maintaining these vessels' long-term integrity while waterborne and the indirect facility and support costs associated with this maintenance. These costs are higher than what either the Navy or MARAD presently expends in passive storage of ships awaiting disposal. In addition, ships are subject to regularly scheduled inspections and tests of their critical systems (e.g., CP and DH equipment and fire and flood alarms), and ships require physical security.

Periodically (we assumed once every 15 years, as recommended to us by MARAD) these ships undergo maintenance in dry dock. This involves costs as-

sociated with docking and undocking; hull cleaning; hull survey; replacement of hull zincs, shaft seals, and rudder seals; hull repairs; and similar items.

We also assumed that annual costs for preservation maintenance would increase by 0.5 percent to account for ship aging and the likelihood that as the ships age they will require slightly more such maintenance each year. Table 2.1 summarizes the cost factors for the long-term (100-year) storage option.

Note in the table the difference in costs for long-term storage versus short-term storage in anticipation of disposal. The Navy's long-term cost is about 15 percent higher than its short-term cost; MARAD's long- and short-term costs differ by a factor of 2.5. Selection of the long-term storage option thus will require each agency to increase its present storage budgets, although we cannot say by how much at this point because we have not analyzed the agencies' current budgets.

Based on the assumptions in Table 2.1, the baseline cost for long-term storage of the 358 ships in a 100-year program is $4.9 billion in undiscounted constant dollars.[1] The annual cost ranges from $45 million to $60 million and averages

Table 2.1

100-Year Storage Option Cost Factors

Factor	Value	Note
	Navy	
Annual preservation maintenance for "scrap" ship	$57,000	Weighted average of all ship sizes (PMS 333)
Annual preservation maintenance for long-term storage	$65,500	Annual preservation maintenance for scrap ship + 15% for CP and DH (PMS 333)
Dry dock cost	$1,230,000	Norfolk Naval Shipyard estimate[a]
	MARAD	
Annual preservation maintenance for "scrap" ship	$20,000	MARAD value for nonretention ship
Annual preservation maintenance for long-term storage	$50,000	MARAD value for non-RRF retention ship
Dry dock cost	$900,000 first dry dock, $800,000 thereafter	MARAD value; first dry dock costs more due to fuel removal
	Both	
Cost growth	0.5% per year	RAND estimate

[a]Costs are associated with various ship types: FF = $1,103,000 (one shaft), CG = $1,230,000 (two shafts), CV = $2,156,000 (four shafts).

[1]Note that total cost is in constant FY00 dollars with no consideration of inflation. In the out years, inflation will increase the actual budget required.

$50 million during the 100-year interval. The breakdown between the total 100-year Navy and MARAD annual preservation maintenance and dry dock maintenance for the existing distribution of ships between Navy and MARAD facilities is shown in Figure 2.1.

The annual Navy and MARAD costs for the long-term storage option are illustrated in Figure 2.2. The higher cost for both agencies in the first year results from the installation of CP and DH systems in ships not presently equipped with these features, which we believe are necessary for long-term storage. The slight dip in MARAD costs at year 16 represents the slightly lower cost of the second and subsequent MARAD dry dock maintenance periods.

Note that excepting the first year, the total cost for both agencies is fairly flat at about $45 million per year. In the out years, the budget will gradually increase to about $55 million per year total as the growth factor of 0.5 percent per year slowly builds.

We assumed for our analysis that of the 358 ships in the inventory, 225 are in MARAD storage and 133 are in Navy storage, because that distribution approximates the current situation. From the detailed calculations in the model, MARAD's storage costs for their ships will thus be about $2.7 billion while the Navy's will be about $2.2 billion. Dividing the total costs by the number of ships held by each agency shows that the cost of storing a ship for 100 years will be

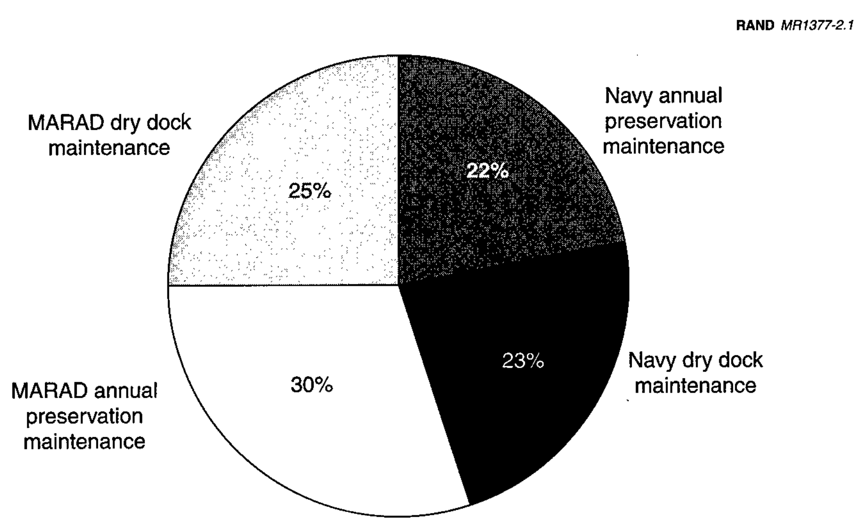

Figure 2.1—Navy and MARAD Annual Preservation and Dry Dock Maintenance for the Long-Term Storage Option

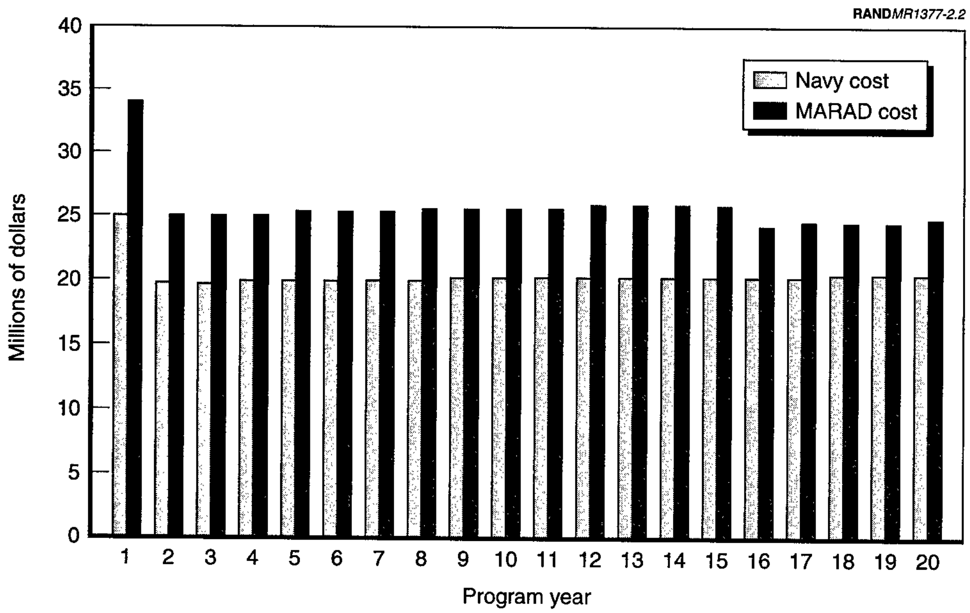

Figure 2.2—Navy and MARAD Annual Costs for Long-Term Storage, First 20 of 100 Years

about $12 million in a MARAD facility and about $17 million in a Navy facility.[2] Thus, for the storage option, MARAD facilities are preferred. In fact, if all 358 ships were stored in MARAD facilities and maintained in accordance with MARAD practices, the total estimated long-term storage program cost would drop from $4.9 billion to about $4.3 billion.

MAJOR CONCERNS

We have two major concerns related to our estimated costs for long-term storage (regardless of storage agency): (1) that leaks will discharge harmful materials into the waterways where the ships are stored, and (2) that corrosion will ultimately penetrate the ships' hulls or topsides, causing them to sink or become unsafe to work aboard. The Navy is addressing the first issue by removing fuels and lubricants from the ships in its custody. However, we understand that MARAD has no current program of this nature and have noted from a brief review of liquid loading logs for some MARAD ships that many still contain po-

[2]We have not determined the basis for the difference between the Navy and MARAD storage costs. The difference could reflect genuine differences in work, different accounting practices, and/or other factors. The cost figures were provided by each of the agencies and are used at face value in our evaluation.

tential pollutants. As the current inactive ships age and corrosion takes its inevitable toll, accidental spills and discharges become more likely. Corrosion alone is a severe problem in these ships, regardless of concerns for potential pollutants. Corrosion of hulls and topsides has already damaged some ships to the point that repairs have been needed simply to keep the ships afloat and adequately safe to work aboard. The ultimate toll of corrosion is unknowable.

With careful and continuous preservation and periodic dry dockings, ships could be kept afloat indefinitely. But the cost and extent of the needed preservation cannot be accurately predicted. We included in our estimates an escalation of 0.5 percent per year for added general maintenance over the duration of the storage period. The actual escalation in maintenance cost for long-term storage, if any, is unknown. Maintenance costs for operating warships escalate at 1 or 2 percent per year of ship age,[3] but maintenance of an inactive ship is very much different from maintenance of an operating ship. We judge that 0.5 percent is a fair estimate. The cost model also has a dry dock maintenance interval of once every 15 years for each of the 358 ships, based on MARAD's recommendation. The required dry dock interval may be different.

The variable that will have the most pronounced effect on total program cost is the aging factor. If it is 2 percent rather than 0.5 percent, the total cost of the long-term storage option nearly doubles, going to $8.6 billion. The dry dock cost and interval factors have a lesser, but still notable impact—each could increase total program cost by another $1 billion.

The ultimate cost of this option is of course difficult to predict: a long-term program of 20 years, to say nothing of 100 years, involves so many unknowable events. However, we estimate that the best case for this option is represented by zero aging growth (essentially assuming that all aging effects will be taken care of during periodic dry dock maintenance), no sudden natural events (such as hurricanes), and no transforming legal changes (such as prohibitions on storage afloat of the materials and substances incorporated in the ships). This best-case estimate also assumes that all 358 ships are stored in MARAD facilities, whose storage costs appear to be lower than those of Navy facilities. With these assumptions, the best-case estimate of total cost for the long-term storage option falls to $3.8 billion. We also estimate that the worst-case cost, which is for a 1 percent aging factor, dry docking repair costs 25 percent higher than those for the baseline estimate, and dry docking intervals every 10 rather than 15 years, would be $7.7 billion.

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[3]John Birkler et al., *The U.S. Aircraft Carrier Industrial Base: Force Structure, Cost, Schedule and Technology Issues for CVN 77*, MR-948-NAVY/OSD, RAND, Santa Monica, CA, 1998.

CONCLUSIONS

According to our assessment, then, the long-term storage option not only is very expensive but also has a large amount of cost uncertainty. Furthermore, this option does nothing more than defer the problem of how to dispose of these ships, leaving some other generation to deal with it. No matter how long the ships are stored—20, 50, or 100 years—there will still be 358 ships for disposal.

For these reasons, we concluded that long-term storage was not a viable course of action and thus not a sound policy option. However, it should be noted that if circumstances were to compel the Navy and MARAD to store the 358 ships for the indefinite future, the MARAD facilities, which appear to offer a lower cost than the Navy facilities do, are the preferred storage location.

Chapter Three

DOMESTIC RECYCLING

Ship recycling has always operated on the basic principle that the value of the scrap and reusable materials extracted from an unneeded ship will exceed the cost of purchasing the ship and dismantling it. For decades, the Navy surrendered its unneeded ships to the Defense Reutilization and Marketing Office, which sold them to recyclers, foreign or domestic, and passed the proceeds to the U.S. government. MARAD had its own process, enforced by the National Maritime Heritage Act of 1994 and its predecessors, which required it to sell unneeded ships in a manner that maximized return to the government. This historic pattern recently broke down, and the government now must pay for recycling services. This chapter explains the basis for the breakdown and develops an estimate for the cost of a program to recycle all 358 inactive Navy and MARAD ships given today's circumstances.

THE DOMESTIC SHIP RECYCLING INDUSTRY

The conventional U.S. ship recycling industry is nearly extinct. Its demise, attributable to many causes, is clearly evident in Table 3.1, which shows how Navy ships were disposed of between 1970 and 1999.

In the 1970s, recycling was the primary means of disposing of Navy ships. In the peak year of 1974, 75 firms were involved in this work, and only eight of them were foreign. While some of the U.S. firms were export brokers, at least 30 were domestic recyclers.[1] MARAD records also confirm a healthy domestic recycling industry during the 1970s, one that was adequate to handle the disposal of most unneeded U.S. government ships. According to a U.S. government report, the U.S. government domestically disposed of 1,449 ships from 1970 to 1989, only 351 of which were recycled overseas.[2] Ship disposals fell off in the

[1]Maritime Administration, *Report on the Program for Scrapping Obsolete Vessels*, Report MA-2000-067, March 10, 2000.

[2]*Report of the Interagency Panel on Ship Scrapping*, USGPO, Washington, DC, April 1998, p. 10.

Table 3.1

Disposal of Navy Ships, 1970–1999

Year	Donated to Museum or Government Organization	FMS or Lease	Transfer to Foreign Military	Recycled by Domestic or Overseas Firm	Sold to U.S. Firm for Other Purpose	SINKEX	Reefing	Total Disposals
1970	4	15	2	75	10	20	0	126
1971	0	60	1	112	23	9	0	205
1972	5	72	1	123	19	15	0	235
1973	6	57	5	165	14	19	0	266
1974	7	31	10	225	16	14	0	303
1975	8	17	4	182	10	11	0	232
1976	7	15	3	80	8	15	0	128
1977	4	17	3	46	7	7	0	84
1978	4	13	2	26	2	11	0	58
1979	3	7	1	32	11	3	0	57
1980	0	7	0	27	4	3	0	41
1981	1	5	0	22	1	1	0	30
1982	13	6	0	26	13	6	0	64
1983	2	3	2	13	1	5	0	26
1984	10	0	0	11	1	1	0	23
1985	3	1	2	3	3	1	1	14
1986	5	0	2	8	1	2	0	18
1987	2	8	2	25	9	3	0	49
1988	1	0	0	6	2	1	0	10
1989	5	13	0	6	3	2	1	30
1990	10	1	0	9	3	4	0	27
1991	1	7	1	5	0	5	1	20
1992	9	10	2	8	0	2	1	32
1993	4	9	10	6	4	5	0	38
1994	9	20	4	16	19	1	0	69
1995	9	1	3	8	17	0	0	38
1996	0	9	3	6	1	0	1	20
1997	3	6	3	14	15	4	0	45
1998	12	4	2	0	17	5	0	40
1999	1	6	2	4	0	3	0	16
Total	148	420	70	1,289	234	178	5	2,344

NOTE: Information is from a 30-year disposal history derived from the ship disposition history provided by NAVSEA PMS 333.

1980s as the Navy built toward a fleet of 600 active ships and MARAD kept its Reserve Fleet (RF) at high levels to support national contingencies.

Recycling has thus been the dominant form of Navy ship disposal, with all other means except reef building being important contributors. MARAD reports a similar pattern. During the four years from 1991 through 1994, about 20

MARAD ships were recycled each year, all but one overseas.[3] During the following six years, only a total of four were recycled. MARAD also has a small reef-building program that has accounted for disposal of at least 41 ships since 1972. While 41 is more than the Navy can claim for reef building, it is but a small fraction of the hundreds of MARAD ships disposed of by domestic and overseas recycling during this 28-year period.

In the 1990s, the Navy reduced the size of its fleet in response to the end of the Cold War. Beginning in the early 1990s, recycling of Navy ships thus should have increased to somewhere between 25 and 50 ships per year. But as seen in Table 3.1, it actually fell from 147 total ships in the 1980s to 76 total ships in the 1990s. Even this total of 76 turns out to be too high. The Interagency Panel reports that from 1991 through 1997, 20 ships sold for domestic recycling had to be recovered from defaulting yards,[4] which puts the true total closer to 50 ships. The recycling rate was then nil—until the Navy initiated paid disposal of ships via the Ship Disposal Program (SDP). MARAD has suffered a similar paralysis of its once robust domestic recycling program.

The result: a steady accumulation of unwanted ships during the 1990s. If we count ships on hand and ships that will enter the inactive fleet from continued retirements of Navy ships through the year 2005, and allow for anticipated FMS, donations, and other nonrecycling means of reducing the inactive ship inventory, approximately 358 ships totaling about 2.8 million LSW tons will be in need of disposal. Of these, 206 were originally Navy ships, although many have had their titles transferred to MARAD for final disposal. Of the remaining ships, 145 were originally MARAD ships and seven were from other U.S. government agencies, primarily the U.S. Coast Guard.

The reasons for the decline of the U.S. ship recycling industry are varied. The dearth of available ships in the 1980s certainly strained the industry's capacity to stay alive, at least to the extent government ships sustained it. The discovery of PCBs in nonmetallic materials in Navy ships in the early 1990s and in MARAD ships in 1997 further affected the industry.[5] PCBs are subject to stringent EPA regulations found at 40CFR761, and having to control PCBs during ship recycling has certainly strained the recyclers' profit opportunities. Also, the EPA rules forbid the export of PCBs, so their presence prohibits the export of ships for recycling. (Appendix C discusses this problem in detail.) A further contributor is the impact of safety and health regulations. Because of reports of envi-

[3]Ibid.

[4]Ibid.

[5]Maritime Administration, *Environmental Assessment of the Sale of National Defense Reserve Fleet Vessels for Scrapping*, Report MA-ENV-820-96003, July 1997.

ronmental and safety concerns, the industry has received increased attention from federal and state regulators, further increasing costs. Finally, the value of the industry's primary product, scrap metal, is erratic and has been very low in recent years. (See Appendix D.) All together, costs are up, profits are down, and the industry, under the old paradigm, appears unable to make money in the United States.

International ship demolition data show that the overseas ship recycling industry is healthy and confirm the weakness of the U.S. ship recycling industry. The Lloyd's Maritime Information Services demolition database records the fate of ships on the Lloyd's register of shipping, which means it includes nearly all recycled merchant ships in the world but excludes recycled U.S. and foreign naval ships and any recycled U.S. government merchant ships that were not on the register.[6] Lloyd's reports that 7,235 merchant ships totaling about 83 million gross registered tons (GRT) were recycled throughout the world during the 1990s and, of these, 141 were U.S. ships totaling 2 million GRT, including 45 ships owned by MARAD.[7] Only eight of the 141 ships (along with seven non-U.S. ships) were recycled in the United States, and all were recycled before 1997. All of the ships recycled in the United States averaged only 1,600 GRT, which means towing them overseas probably was deemed uneconomic, and all were privately owned.[8] According to Lloyd's, then, the U.S. recycling industry is virtually nonexistent, and even the owners of U.S. ships (including MARAD) have taken their business elsewhere. This is not to say that the United States does not have a vibrant scrap industry. U.S. firms generate over 65 million tons of ferrous scrap alone, most of which is consumed in the United States.[9] However, ships make up a minute fraction of the total.

The Navy's answer to the dilemma of a growing Navy ship inventory has been varied:

- The Navy is transferring as many unneeded ships as possible to MARAD ownership and custody. In fact, the majority of the ships in the MARAD inventory originally came from the Navy. This transference reduces the

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[6]Lloyd's Maritime Information Services, "Demolition Database," October 2000. Also not included are recycled small local craft, barges, and tugs, nor U.S. warships scrapped domestically.

[7]Gross registered tonnage is a measure of the cargo-carrying volume of a merchant ship. One GRT equals 100 ft^3 of cargo-carrying space. There is no set relationship between GRT and LSW. The larger the ship, the more the gross tonnage per ton of ship weight. Indian scrap authorities report that the conversion factor for the average scrap ship in recent years has been LSW = GRT $\times$ 0.39.

[8]The 81 ships that MARAD reports as having been recycled in the United States early in the decade do not appear on the Lloyd's demolition database. This may be because many were of U.S. Navy origin and thus were not listed on the Lloyd's register.

[9]*The Commodity Research Bureau Commodity Yearbook*, 1994, Knight-Ridder Financial/Commodity Research Bureau, John Wiley and Sons, Inc., New York, 1994.

Navy's inactive fleet maintenance costs but increases MARAD's costs. Overall, the government appears to benefit because the reported cost of maintaining a Navy ship to Navy standards in a Navy facility is higher than the reported cost of maintaining a ship in a MARAD facility. (See Chapter Two, Table 2.1, for information on comparative storage costs.)

- Military training exercises termed "sinking exercises," or SINKEX, were once a consumer of unneeded ships, averaging about 8 percent of all disposals over the past three decades (see Table 3.1). These exercises were brought to a halt in the early 1990s when PCBs were discovered on ships and legal theory held that the exercises constituted the unlawful disposal of PCBs at sea. The Navy recently concluded negotiations with the EPA that permit the exercises to continue, but they will consume no more than a few ships per year, not enough to solve the growing-inventory problem.
- Many retired Navy vessels have been sampled for the presence of PCBs in hopes of finding some that do not have the problem and thus might be disposed of more easily. This effort has met with limited success. (See Appendix C for more information on PCBs in ships and the constraints their presence places on disposal options.)
- The Navy has attempted to bundle ships for recycling as a way to offer potential recyclers economies of scale from larger amounts of tonnage. This effort has not met with success. The environmental and safety challenges have proven to be insurmountable under the old ship recycling paradigm, regardless of the size of the deal.

While these actions by the Navy have met with some success in controlling the inventory of unneeded ships at Navy facilities, MARAD has had little or no success in disposing of ships and is faced with added legal impediments and with managing a growing inventory of Navy transfers. The National Maritime Heritage Act of 1994 requires MARAD to sell unneeded ships in a manner that maximizes return to the U.S. government and to dispose of all obsolete vessels in its inventory no later than September 30, 2001. The Department of Transportation's inspector general recently concluded that because of the domestic and foreign difficulties with PCBs and the failed state of the U.S. ship recycling industry, MARAD cannot possibly comply with this requirement.[10] In the Floyd D. Spence National Defense Authorization Act for FY2001, MARAD was authorized to purchase scrapping services in a manner comparable to how the new Navy does in its SDP. Thus both agencies now find themselves having to pay for domestic ship recycling.

[10]Maritime Administration, *Report on the Program for Scrapping Obsolete Vessels.*

INDUSTRIAL CAPABILITIES

Puget Sound Naval Shipyard (PSNS) has been recycling Navy nuclear-powered warships for about 10 years. The Navy also has four contractors currently engaged in recycling conventional warships in its SDP. PSNS and two of these contractors—Baltimore Marine Industries of Baltimore, Maryland, and Metro Machine of Philadelphia, Pennsylvania—provided us with estimates of the industrial capabilities needed to conduct recycling at their facilities. Each estimated that they could recycle up to 40,000 LSW tons per year while employing no more than 800 workers using existing graving docks, floating dry docks, and owned or rented crane and scrap cutting machinery.

We constructed a notional recycling program that could recycle all 358 ships within 20 years. Based on the industrial capability estimates the three organizations supplied, four recycling facilities would be sufficient. While shorter or longer programs employing different numbers of facilities can be envisioned, a 20-year program spreads out the work in a way that assures the expenses involved will represent only a relatively small claim on the Navy and MARAD budgets in any one year. Therefore, a 20-year program is the basis of our estimates.

But given the weak state of the U.S. ship recycling industry, is it reasonable to expect four facilities to operate reliably and continuously over 20 years to finish the job? There would have to be adequate labor and adequate facilities. Regarding labor, the U.S. ship construction and repair industry has been declining at an annual rate of about 7 percent for many years and presently employs about 57,000 production workers. The annual loss in recent years averages about 4,000 workers. The number of workers required to staff four notional ship recycling facilities is thus within the recent fluctuation of employment in the ship construction and repair industry, and the workers are likely to be available on the local labor market. Further, the skill level for recycling is low and can be drawn from local unskilled labor, as demonstrated recently by SDP contractor Metro Machine. Regarding facilities, many and perhaps all recycling yards will require a graving dock or floating dry dock to fully contain the debris and liquids generated during ship recycling, at least in the latter stages of a ship recycling job. There are about 28 active graving docks in the United States and Puerto Rico, and there are many more inactive docks at former U.S. Navy and private shipyards. There are also floating dry docks that can be used.

The Navy's SDP has clearly demonstrated that labor and facilities are not an issue, so long as the yard is assured of profit. The four winning bidders for the first increment of the SDP include new and old companies using new and old facilities. Baltimore Marine Industries is using its existing ship repair facilities with a few minor additions. Metro Machine is using both existing ship repair

facilities and old ship construction facilities that have been restored. International Shipbreaking Limited is using existing ship recycling facilities; Ship Dismantling and Recycling Inc., a new company, is using old, restored ship repair facilities. Even the existing U.S. Navy shipyards each have the facilities to recycle all or nearly all of the 358 ships.[11]

We conclude that available U.S. private and government industrial capabilities are adequate to staff and sustain a 20-year U.S. ship recycling program.

THE COST OF A DOMESTIC RECYCLING PROGRAM

In our cost analysis, a program for recycling a fleet of ships has four discrete elements:

1. The cost to dismantle ships, i.e., the cost of all the work done at the recycling shipyard or facility.
2. The revenue (or negative cost) from selling the scrap metal and reusable equipment from the ship.
3. The cost to prepare ships for towing and to tow them from their storage sites to the dismantling site.
4. The cost to store ships while they wait to be recycled.

Item 1 consists of all costs to cut a ship apart, sell what can be sold, dispose of wastes that cannot be sold, and comply with all federal, state, and local rules while performing this work. We use the term *dismantling* to represent this part of a recycling program. Other costs here include labor, the recycler's management and overhead expenses, the cost of subcontracts (such as for equipment rental and waste management), marketing costs for selling scrap and reusable equipment, and the recycler's profit. Items 2, 3, and 4 are self-explanatory. For this analysis we assumed that a domestic recycling program would take 20 years and calculated the total cost spread over that period. An actual program may take more or less time depending on the availability of funds and the competency of the recycling contractors.

By adding items 1, 3, and 4 together, subtracting item 2, and summing across the entire fleet of ships for disposal, we arrive at the total program cost. The following sections discuss how we arrived at values for these four recycling program cost elements.

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[11]For example, the Portsmouth Naval Shipyard in Kittery, Maine, which is devoted to repair of Navy submarines, has the facilities to recycle all but the largest of the ships in the inventory.

Estimating the Cost of Dismantling

The baseline for estimating dismantling costs comes from two sources, the Navy's SDP and PSNS. Through the SDP, the Navy pays shipyards or ship recycling facilities to dispose of ships and in return expects to acquire enough cost information to develop a long-range budget for disposal of all unneeded Navy ships over the next several years. Thus far, contracts have been awarded and completed for four ships, one at each of four facilities, and cost returns are in for all four. Additional contracts will soon be awarded, and a similar project is under way in MARAD (no reported results so far). OPNAV N43B provided us with data from the four SDP contractors broken down into total yard dismantling cost; total subcontract cost; waste management cost; overhead, general, and administrative costs; and proceeds from the sale of scrap and reusable equipment. To protect the proprietary interest of the recycling yards, none of this information is reproduced in this report. However, we can say that the average total dismantling cost (not corrected for revenues) for a DE1052 Class ship having an LSW of approximately 3,011 tons is $1,253 per LSW ton.[12]

The Navy has also confronted the issue of ship recycling in a very different context: unneeded nuclear-powered submarines and surface ships. Because of the special nature of nuclear-powered ships, a U.S. government funded program executed almost entirely at the PSNS in Bremerton, Washington, has done the recycling work. In fact, it was during this program in 1989 that the problem of PCBs in nonmetallic industrial materials was first made known to the Navy. Because of PSNS's decade-long experience in dealing with the process of ship recycling in compliance with all environment and safety rules, we solicited from PSNS an estimate of the cost to recycle a non–nuclear-powered U.S. Navy warship in accordance with their practices in a civilian environment. PSNS provided us with an estimate of labor hours and direct costs, as shown in Table 3.2.

The labor rate of $45 per hour used in the table is the average of West, East, and Gulf Coast private shipyard fully burdened rates ($38 to $53 per hour) and government maritime facility fully burdened rates ($34 to $56 per hour). Note that this estimate is expressed almost entirely as a labor cost; so a facility with a labor cost of, say, $22.50 per hour could accomplish the job for about half of our estimate.

[12]This is the nominal new-construction LSW for DE1052 Class ships recorded in Paul H. Silverstone, *U.S. Warships Since 1945*, Naval Institute Press, 1986. Throughout this report, we use the approximate new-construction LSWs reported in the open literature. Warships usually grow in LSW during their service life as new systems are added. Therefore, any specific ship is likely to weigh more at the end of its life than is recorded in the literature. We elected not to determine the exact weight for each ship, because the effort involved was not commensurate with the gain. The overall effect is to underestimate the total tonnage of shipping awaiting disposal.

Table 3.2

PSNS Recycling Cost Estimate

Total man-days	26,426
$/man-day @ $45/hour	360
Labor cost	$9,513,360
Consumables cost	110,385
Total labor and material	9,623,745
Waste disposal	500,000
Total	10,123,745
Notional LSW	5,500
$/ton	1,841

The cost data from these sources are only for small warships. The SDP returns are all for DE1052 Class warships, which are at about 3,011 LSW tons. The PSNS estimate is for a notional nonnuclear surface combatant warship of about 5,500 LSW tons. Table 3.3 summarizes the recycling cost per ton for the PSNS estimate and the four SDP contractors and provides the average of the five data sources.

In terms of tonnage, Table 3.3 covers only a narrow range of ships. Appendix A, Table A.2, shows that the vessels in need of disposal now or over the next 20 years range from very small, 175-ton (LSW) barges to the 63,000-ton (LSW) *Glomar Explorer* presently on long-term lease for continued use. Table 3.3 also covers only a narrow degree of ship complexity. Compared to most merchant ships, warships have many decks and compartments and are more densely packed with equipment, which may make them more difficult to recycle (per ton of ship) than the larger, simpler auxiliaries or merchant ships. Also, most warships are small compared to merchant ships, so they could not take advantage of any economies of scale that might permit larger, heavier ships to be recycled for less per ton of weight. We needed to find a way to extrapolate the limited data to a wide range of vessels in terms of complexity and weight.

Table 3.3

Cost per Ton for Domestic Recycling

Activity	Net Cost ($/ton)	Average LSW (tons)
PSNS	1,841	5,500
SDP contractor average	1,253	3,011
PSNS and SDP average	1,371	3,633

Accounting for Ship Complexity and Weight

We realized that warships are usually more complicated than merchant ships and that ship complexity must be accounted for in any reliable estimates. We also realized that ship weight might be important in estimating reliability because recyclers might gain economies with heavier ships. To account for relative complexity and ship size in our cost estimates, we pursued three different approaches.

1. The Ship Complexity Factor. In this approach, we use an extrapolation factor that is based on the ratio of the construction labor required per ton of ship for different types of military ships and for an average merchant ship. This approach assumes that the amount of labor to recycle a ship will be proportional to the labor to build it.

The ship complexity factor is derived from average man-hours per ton of ship for Navy new construction. Table 3.4 shows the averaged data and the resultant complexity factors rounded to the nearest tenth.

The formula for estimating the recycling cost for any particular ship from the complexity factor and Table 3.3's average domestic recycling cost is $1,371 × CF × LSW. For example, for a 10,000-ton surface combatant, the estimated domestic recycling cost in the first year of the program would be 1,371 × 1 × 10,000 = $13.7 million. If this notional ship were instead an amphibious warfare ship, the complexity factor would predict a first-year cost of $9.6 million; if a merchant ship, the first-year cost would be $2.7 million. Once again, this estimate is only for ship recycling. It does not include revenue offsets from the sale of scrap and reusable equipment; the costs of tow preparation, towing, and storage while awaiting recycling; or the benefits of experience a recycler would be expected to gain in a repetitive long-term project.

No data were available on new construction man-hours per ton for merchant ships. The amount of labor required to build merchant ships is closely guarded

Table 3.4

Ship Complexity Factor

Ship Type	New Construction (man-hours/ton)	Complexity Factor
Surface combatant	600	1
Aircraft carrier	460	0.8
Amphibious warfare	400	0.7
Auxiliary	150	0.3
Merchant	—	0.2

SOURCE: NAVSEA 017, Cost Engineering and Industrial Analysis Division.

by the yards. The merchant ships described in Appendix A, Table A.2, are approximately comparable in size and payload to corresponding Navy auxiliaries. However, unlike auxiliaries, merchant ships do not carry large crews, do not have capabilities for onboard maintenance, and often do not have systems for replenishment at sea. Because of these simplifications, we assumed that merchant ships in the MARAD inventory will require one-third less labor per ton to build than Navy auxiliaries and accordingly assigned a complexity factor of 0.2.

The complexity in building a warship is often in the labor needed to assemble and test very complex weapons and ship hull, mechanical, and electrical systems. Very little effort is required to remove these systems during recycling, however. We wanted to ensure that the ship complexity factor not overrate the actual recycling differences between complex and simple ships, so we sought other means to extrapolate the starting-point datum.

2. The Reef Preparation Factor. This approach is based on the cost to prepare a number of ships for reefing. Reef preparation requires some of the same work as recycling (such as cleaning the tanks, removing hardware, and cutting holes in decks and bulkheads) but less of it. The data for reef preparation show that the cost per LSW ton declines as the displacement of the ship increases and appears to be uncorrelated with ship complexity. We normalized the reef preparation data to the weighted average PSNS and SDP recycling cost datum based on the assumption that the same relationship would hold true for recycling cost.

The reef preparation factor is shown in Figure 3.1. The data plotted in the figure are from Chapter Five, Table 5.2, Costs to Prepare Ships for Reefing. A trend line has been fitted to the data and is shown as a solid line. The equation for this trend line is shown below the data and the solid line. We used this equation to calculate that the first-year program cost to prepare a ship for reefing that has an LSW of 3,011 tons will be $247 per ton for a total cost of $0.7 million. Similarly, the first-year cost to prepare a 5,500-ton LSW ship for reefing would be $184 per ton for a total cost of $1.0 million. The data points in Figure 3.2 are based on actual cost returns for preparing ships for reefing or on estimates of the costs from experienced organizations such as the U.S. Coast Guard, Navy, and privately operated shipyards. The data are tightly clustered about the line, suggesting a very good correlation between recycling cost and LSW.

If we assume that the complexity of recycling a ship will follow a cost-versus-LSW curve parallel to that for preparing a ship for reefing, we can normalize to the weighted average PSNS and SDP cost datum and apply the result to the inventory of inactive ships. The average first-year cost per ton for recycling ships is given in Table 3.3, and the normalized curve passing through this datum is shown as a dashed line in Figure 3.1. The average ship is 3,633 tons, and the

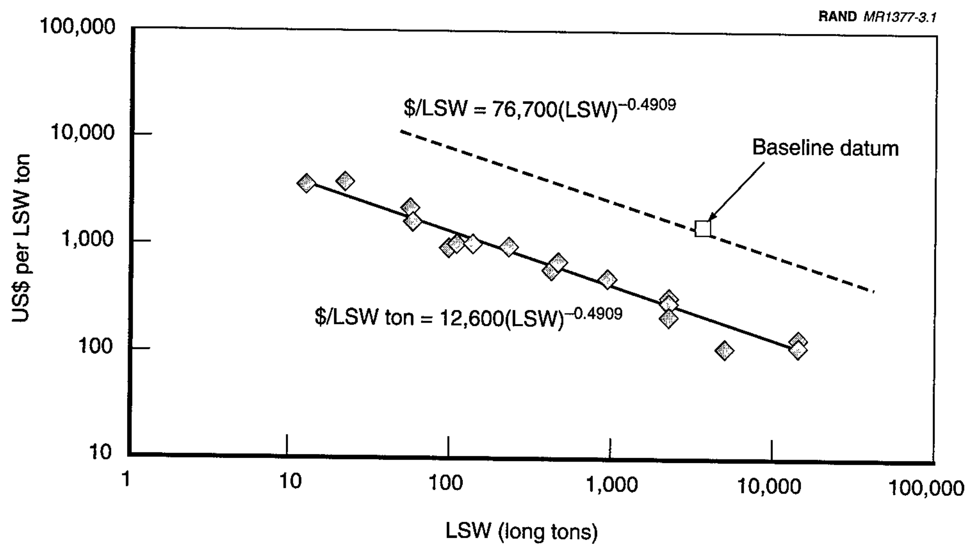

Figure 3.1—Reef Preparation Factor

average recycling cost (from Table 3.3) is $1,371 per ton. The resulting equation is also shown in the figure above the dashed line and normalization datum.

For the notional 10,000-ton ship (regardless of type), the reef preparation factor predicts a first-year domestic recycling cost of about $8.3 million. In terms of recycling cost per ton in the first year of a program, the predictions are $1,838 for a 2,000-ton ship, $1,172 for a 5,000-ton ship, and $834 for a 10,000-ton ship. Using this relationship, the average first-year recycling cost for all 358 ships in the fleet works out to $863 per ton exclusive of the learning curve, towing expenses, and revenue from the sale of recovered scrap and equipment.

3. Indian Labor Versus Tonnage Factor. We have data from recyclers in India showing that the use of skilled labor (riggers, torch cutters, and cutter helpers) declines as the tonnage of the ship increases. There is no reported correlation with complexity, only tonnage. Ship recycling is very different in India than in the United States. For example, U.S. recyclers must comply with more-demanding environmental and safety requirements and use a higher level of technology. Also, most if not all U.S. recyclers use oxy-acetylene torches, whereas the standard for Indian recyclers is the lower-temperature and slower-cutting liquefied natural gas (LNG) or liquefied petroleum gas-oxygen (LPG-oxygen) torches. Additionally, Indian recyclers cut ships into pieces weighing no more than about 400 pounds so that a gang of men can lift the pieces by hand and load them into trucks for transport to steel mills. In the United States, nearly all lifting is done by crane or fork lift. But assuming that the labor effi-

ciencies in both countries improve with ship size at the same rate, and assuming that other costs are in proportion to labor, the Indian labor data normalized to the weighted average PSNS and SDP recycling cost datum provide a third way to estimate domestic recycling costs.

In terms of labor versus tonnage, Indian ship recyclers report that the skilled labor for recycling ships varies with total ship size but not with ship type.[13] This conclusion includes the recycling of naval ships in India, but the Indian sources are silent on the specific types of naval ships that have been recycled. The Lloyd's ship demolition database (described earlier) does not include data on naval vessels because such ships are not registered with Lloyd's. However, trade literature indicates that the government of Russia has sold many surface combatants and other warships to Indian recyclers in recent years.

Figure 3.2 shows the available data on recycling labor-hours per ton for skilled labor in Indian recycling yards. As can be seen, a small ship of about 2,000 tons LSW will require about 7 man-hours of skilled labor per ton to recycle, whereas a large ship of 20,000 tons LSW will require about 3.2 man-hours per ton. For ships smaller than 2,000 tons, the labor requirement climbs rapidly; for ships larger than 20,000 tons the labor requirement is nearly flat. If we assume this relationship holds for the cost of recycling ships in U.S. facilities and normalize

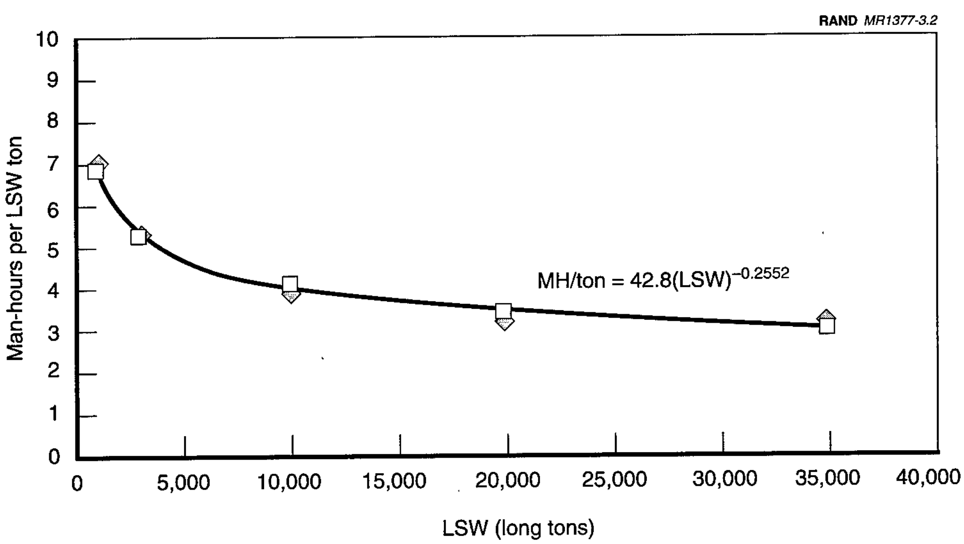

Figure 3.2—Labor vs. LSW for Indian Ship Recycling

[13]Ferrous Scrap Committee, Ministry of Steel, Government of India, *Shipbreaking in India, A Roadmap for Future Development*, undated, p. 70.

it to the weighted average PSNS and SDP recycling cost datum, we obtain $/LSW-ton = 11,107 × LSW$^{-0.2552}$. Applying this approach to three ship sizes, we predict that a 2,000-ton ship will cost $1,597 per ton to recycle in the first year of a program, a 5,000-ton ship will cost $1,264, and a 10,000-ton ship will cost $1,058.

Table 3.5 compares the predictions arrived at through our three cost-estimating approaches for three types of ships at three different sizes.

As is evident, the three approaches predict significantly different first-year costs for all ships. However, our primary interest in this analysis is to estimate the cost of a domestic recycling program for all 358 ships in the combined Navy and MARAD inventories (see Table A.2). Applying the three approaches to the inventory yields the following results for the cost to recycle all 358 ships. (Recall that these costs are solely for dismantling and thus do not include towing and other program costs or cost reductions such as revenues from selling scrap or the learning curve.)

$1.3 billion for the ship complexity factor

$2.4 billion for the reef preparation factor

$2.9 billion for the Indian labor vs. tonnage factor

The complexity factor approach predicts the lowest overall cost for recycling the fleet. The reason for this can be seen in Table 3.5, where, compared to the other approaches, the complexity factor approach produces very much lower costs to recycle merchant ships (complexity factor of 0.2) and, by extension, auxiliary ships (complexity factor of 0.3). Because these ships make up about 53 percent of the total ship inventory by LSW, their lower estimated recycling costs significantly affect the total program recycling cost.

Table 3.5

Comparison of Cost-Estimating Approaches for First-Year Cost per Ton

Ship Type	Surface Combatant			Amphibious Warfare			Merchant		
Ship LSW	2,000	5,000	10,000	2,000	5,000	10,000	2,000	5,000	10,000
US$/ton using complexity factor	1,371	1,371	1,371	960	960	960	274	274	274
US$/ton using reef preparation factor	1,838	1,172	834	1,838	1,172	834	1,838	1,172	834
US$/ton using Indian labor vs. tonnage factor	1,596	1,263	1,058	1,596	1,263	1,058	1,596	1,263	1,058

Estimating the Error in the Recycling Cost

Although our cost estimate for the domestic recycling option uses all available data, there were not enough data to permit a rigorous statistical analysis. The factor used to renormalize the reef preparation cost curve was derived from five data points from PSNS and the SDP. The standard deviation for this average curve is ±30 percent. The complexity curve was renormalized based on a much better data set (25 points) that has very good correlation and a standard error of ±16 percent.

Conclusions on Estimating the Recycling Cost

Our preliminary report of findings to the Navy was based on the ship complexity factor approach described above. At the time of that report, we had not gathered and analyzed information on reef preparation costs or evaluated ship recycling experience in India. Now having done so, and having considered anecdotal information from U.S. parties engaged in ship recycling and reef preparation, we conclude that the complexity factor approach should be discarded. Neither of the two current Navy ship recycler contractors we have corresponded with agreed that there should be a factor-of-5 recycling cost difference between warships and merchant ships, nor is such a spread borne out in the information from Indian recyclers. The difficulty with the complexity factor approach is seen in the case of small ships. For the U.S. Coast Guard's buoy tenders, at 935 tons, the complexity factor approach says that recycling should cost $325,000. But the Coast Guard is budgeting $500,000 for reef preparation costs and advises that reef preparation is much less expensive than recycling. The reef preparation factor approach is based on good cost data or near-term estimates for very similar work and shows a clear dependency of cost on ship size. Also, the reef preparation factor approach is supported, in the aggregate, by comparison with the information on labor versus tonnage from Indian recyclers.

The conclusion that the reef preparation factor approach is preferred is not offered without concern, however. The three approaches produce widely varying estimated costs for recycling any particular ship. Within the Navy's SDP, recycling costs among the four contractors varied widely, as did the value of recovered materials. A recent MARAD contract for recycling the merchant ship SS *Builder* was let with a Texas firm for about $1.6 million. After including the value of the recovered material for comparison with our cost-estimating approach, this converts to about $2.1 million.[14] Our estimating method based on

[14]The contract was for $1,557,370, but the recycler was to keep the proceeds from the sale of recovered materials. Based on scrap prices in Houston, Texas—which are higher than elsewhere in

the complexity factor predicts a recycling cost for this ship of about $1.9 million, close to the actual contract price, whereas our reef preparation factor approach predicts a recycling price of about $6.4 million. Many factors could account for this large difference, including the environmental conditions of *Builder*; the environmental, safety, and health conditions imposed on the recycler by local regulators; and the recycler's cost basis, labor rates, and productivity concerns. Also, *Builder* recycling is not yet complete, and the actual costs may end up being higher. Nonetheless, the apparent terms of the *Builder* contract argue that the complexity factor approach may be more accurate for merchant ships. Finally, because the analysis of the reefing data yields a good estimate of the errors involved, we conclude that the reef preparation factor is the most robust approach and have used it in our final cost estimates.[15]

Estimating Revenues from the Sale of Scrap and Reusable Equipment

Our approach to estimating the value of scrap and reusable equipment is described in detail in Appendix B. Table 3.6, reproduced from Appendix B, Table B.12, shows information derived from a historical analysis of the scrap metal market and anecdotal evidence from former ship recyclers on the value of recyclable equipment.

The Navy SDP contractors reported average proceeds of $142 per ton from the sale of scrap and equipment from the four DE1052 Class ships that have been recycled to date and for which we have summary data. The total value in Table

Table 3.6

Average Recoverable Value of Ships in Domestic Recycling

	Weighted Avg. $/Ton	
Material	Navy Ships	Merchant and Other Ships
Steel	44	48
Aluminum	11	0
Copper and copper alloys	16	10
Lead	8	0
Total scrap metal	79	58
Equipment	9	6
Total	88	64

the country—the scrap from *Builder* may bring $550,000. Thus, the recycling cost for *Builder* will be the sum of the two, or about $2.1 million.

[15]Chapter Five discusses the cost of the reefing option. Using the estimating methods of that chapter, *Builder* would cost about $1.1 million to be prepared for a reef—much less than the $1.6 million bid to recycle it.

3.6 is the weighted average for all classes of Navy ships. For surface combatants alone, the total is $130 per ton, which compares well with the SDP results. As discussed in Appendix B, recycle proceeds depend on the very volatile scrap metal market and on the recycling contractor's resourcefulness in finding the best price for scrap and reusable equipment. The issue of revenue differences is discussed at the end of this chapter.

Estimating Tow Preparation and Towing

Towing is a notable cost for any domestic ship recycling program. Inactive Navy and MARAD ships are kept in different locations in the United States, including Hawaii, California, Texas, Philadelphia, and the Norfolk, Virginia, area. In addition, a few ships are at scattered locations. For some recycling yards, towing costs will be minimal for large numbers of ships. For example, a recycling yard at the old Philadelphia Naval Shipyard would have ready access to a large number of inactive ships held at the Naval Inactive Ship Maintenance Facility (NISMF) a few hundred yards away. Similarly, a recycling facility in the San Francisco Bay area would have ready access to ships held at MARAD's Suisun Bay Reserve Fleet, which is also within the bay. Large numbers of ships are also propitiously located in the Norfolk, Virginia, area. Other ship concentrations are in Beaumont, Texas, and Pearl Harbor, Hawaii, some distance from likely recycling yards.

We cannot anticipate the specific recycling sites likely to be involved in a full-scale domestic recycling program or the specific ships that each such contractor might be awarded. Therefore, to arrive at an average towing cost per ship for all 358 ships in the inactive inventory, we first determined an average towing cost per mile and an average towing distance. The resulting per-ship cost of towing was then included in the overall cost of a domestic recycling program.

To complete a domestic recycling program within 20 years, four recycling facilities will have to be fully loaded. We thus assumed that there is one ship recycler in the vicinity of each of the existing Navy SDP contractors—i.e., in the San Francisco Bay area, the Delaware River area, the northern Chesapeake Bay, and the vicinity of Brownsville, Texas—and we assumed that each would be equally loaded.

To determine the towing cost per ship mile, we used information from Crowley Marine Services, Inc., of Seattle, Washington. Crowley provided us with towing cost estimates and towing insurance cost estimates for towing ships between five major storage locations and the assumed recycling sites. Crowley also provided tow rigging estimates. All of our towing cost estimates are affected by the following caveats:

- Our estimates include the approximate cost to purchase private insurance for towing of government vessels, as is required to meet port requirements. Crowley advises that towing insurance can range from 1 to 10 percent of the towing charges depending on route, anticipated weather, trip length, ship value, and ports entered. The highest charges are for the largest ships undergoing the most difficult tows. We estimated that a charge equal to 3 percent of the towing cost would be representative of insurance cost and have included this in our estimates.

- Towing costs are based on towboats running light (i.e., with no ships) to the tow and on the return trip. Towing companies will try to minimize run-light miles. For towing that is not time critical—the case we anticipate for recycling tows—return tows can be arranged roughly half the time. If such tows are arranged, the added revenue to the towing company will be reflected in lower costs to the Navy.

- Towing costs are based on single-ship tows. Two ships can sometimes be towed at one time if they are of similar size and suitably powerful towboats are available. This so-called tandem tow will be slower and thus more expensive per mile, but the overall cost, compared to that for transporting two ships separately, will be lower by 30 to 40 percent.

- All west-to-east tows are assumed to be via the Panama Canal. There are no east-to-west tows in our estimate, because none were needed to achieve equal distribution of ships among the four notional recyclers. No consideration is given to the higher cost of towing aircraft carriers around South America (they cannot transit the Canal). However, because aircraft carriers are presently distributed between East and West Coast ports, no tows around South America should be needed if recyclers on the two coasts are chosen. Regardless, because only eight of the 358 ships are carriers (see Appendix A, Table A.2), the added cost of a tow around South America does not notably affect average cost or total program cost.

- All towing is assumed to be conducted by Crowley using tugboats home-ported in Seattle, Washington, Jacksonville, Florida, and Lake Charles, Louisiana. The lengthy distances between some of these locations and those of the ships to be towed would have caused our estimates to include high running-light costs. To partly correct for this, we eliminated from our calculation any Crowley tow whose ratio of run-light miles to tow miles exceeded 2.4, our assumption being that a less-expensive tow could be found from a company more suitably located. The Navy probably would be able to further lower costs by selecting towing companies headquartered closer to the ship(s) being towed.

Tables 3.7 and 3.8 show the cost estimates and tow distances, respectively. As can be seen in Table 3.7, the average cost per tow mile is $224. To estimate the number and location of ships to be towed and the tow lengths, we used the data from Appendix A, Table A.2, ignoring any presently active ships. Leaving out the active ships has the same effect as assuming that they will eventually be

Table 3.7

Crowley Marine Towing Cost Estimates

From	To	Tug Home-port	Tow Miles	Total Tug Miles	Crowley Estimate	$ per Tow Mile	Ratio of Total Tug Miles to Tow Miles	$ per Total Mile
Suisun Bay	Bremerton, WA	Seattle	871	1,702	204,000	234	1.95	120
Suisun Bay	Brownsville, TX	Seattle	4,759	11,084	1,096,000	230	2.33	99
Suisun Bay	Baltimore, MD	Seattle	5,255	12,080	1,178,000	224	2.30	98
Suisun Bay	Philadelphia, PA	Seattle	5,331	12,207	1,189,000	223	2.29	97
James River	Brownsville, TX	Jackson-ville	1,752	3,660	378,000	216	2.09	103
James River	Bremerton, WA	Jackson-ville	5,890	12,091	1,370,000	233	2.05	113
James River	Hunters Pt, CA	Jackson-ville	5,103	10,758	1,229,000	241	2.11	114
Pearl Harbor	Hunters Pt, CA	Seattle	2,161	5,395	475,000	220	2.50	88
Pearl Harbor	Bremerton, WA	Seattle	2,443	4,846	461,000	189	1.98	95
Pearl Harbor	Brownsville, TX	Seattle	6,693	14,591	1,392,000	208	2.18	95
Philadelphia	Brownsville, TX	Jackson-ville	1,761	3,831	410,000	233	2.18	107
Philadelphia	Bremerton, WA	Jackson-ville	6,048	12,429	1,395,000	231	2.06	112
Beaumont	Baltimore, MD	Lake Charles	1,785	3,651	400,000	224	2.05	110
Beaumont	Philadelphia, PA	Lake Charles	1,833	3,747	410,000	224	2.04	109
Beaumont	Bremerton, WA	Lake Charles	5,634	11,353	1,305,000	232	2.02	115
				Average cost per tow mile: 224				

NOTES:

1. All estimates are based on single tows at 6.0 knots, 12 knots when running light, and 2 days of free time.

2. Fuel cost is calculated at $0.80 per gallon.

3. Tugs start and end the trip at their homeport.

4. All ships are able to transit the Panama Canal.

5. Pilot fees of $5,000, assist tug charges of $20,000, and Panama Canal fees of $95,000, where applicable, are included in each estimate when applicable.

6. No allowance is included for rigging ships for tow or for any special towing gear. Outfitting costs range from about $100,000 for a destroyer to $275,000 for a battleship or jeep carrier. Carriers unable to transit the Panama Canal are estimated at $1,100,000.

Table 3.8

Average Tow Distances

From	To	No. of Ships	Tow Miles	Total Tow Miles
NISMF, Pearl Harbor, HI	Hunters Pt., CA	21	2,161	45,458
RF, Suisun Bay, CA	Hunters Pt., CA	44	10	444
NISMF, PSNS, WA	Hunters Pt., CA	12	1,000	12,000
Alameda, CA	Hunters Pt., CA	2	0	0
Port Hueneme, CA	Hunters Pt., CA	1	380	380
NISMF, Philadelphia, PA	Philadelphia, PA	40	0	0
NISMF, Newport, RI	Philadelphia, PA	1	300	300
Subbase New London, CT	Philadelphia, PA	1	300	300
NISMF, Portsmouth, VA	Philadelphia, PA	16	253	4,048
JRRF, VA	Philadelphia, PA	22	253	5,566
JRRF, VA	Baltimore, MD	66	172	11,352
MARAD, NC	Baltimore, MD	2	300	600
Cheatham Annex, VA	Baltimore, MD	1	600	600
Panama City, FL	Baltimore, MD	5	1,400	7,000
Mobile, AL	Baltimore, MD	2	1,573	3,146
Key West, FL	Baltimore, MD	1	1,175	1,175
RF, Suisun Bay, CA	Brownsville, TX	41	4,759	195,119
RF, Beaumont, TX	Brownsville, TX	41	450	18,450
Houston, TX	Brownsville, TX	2	375	750
	Total	321		306,688
	Average trip distance = 955 tow miles			

distributed among the existing storage facilities in the same ratio that applies to ships presently in those facilities. We also ignored ships currently overseas or for which we had no certain location. We distributed the ships among the four notional recycling sites in roughly equal numbers and so as to minimize towing. For distance between ports, we used estimates from Crowley and from the Defense Mapping Agency.[16]

The average towing cost is $224 per mile and the average trip distance is 955 miles, leading to an average towing cost of $212,800 per ship. An additional $100,000 (the Crowley estimate for rigging a destroyer for tow) is added to account for tow preparation costs, giving a total cost of $312,800 per ship for tow preparation and towing. This per-ship cost was added to the other costs in the cost model.

[16]Defense Mapping Agency, *Distances Between Ports*, Publication 151, 6th ed., 1991.

Estimating Ship Storage Costs

While waiting for recycling, each ship must continue to be maintained in storage by either the Navy or MARAD. Both agencies provided average annual storage costs for a ship awaiting disposal in their facilities: $57,000 for the Navy and $20,000 for MARAD. Note that we are not using long-term storage costs. We assumed that a domestic recycling program would begin with the worst ships first, so there is no need to upgrade the current storage conditions of the 358 ships awaiting disposal. We added a weighted average storage cost for each ship (until each is removed from storage for recycling) based on its current custodian (see Appendix A, Table A.2). We ignored ships not in the custody of either the Navy or MARAD. Presently, 225 ships are in MARAD's custody and 128 are in the Navy's custody, putting the average annual storage cost per ship at $33,400.

We anticipate that storage cost will slowly escalate during the course of a recycling program as ships age and require more maintenance to keep them in adequate condition. We therefore escalate the current weighted average storage cost by 0.5 percent per year. (Chapter Two discusses the influence of the storage cost escalation factor on long-term storage.)

Estimating the Error in the Tow, Storage, and Revenue Estimates

We did not attempt to estimate the errors in the tow preparation and towing costs, storage costs, and revenues from selling scrap metals and reusable equipment. Our estimates are based on point costs that were provided by different parties and that we have not attempted to rationalize. These costs represent about 6 percent of the total domestic recycling program costs, so whatever errors exist will have a proportionately diminished effect on the total program estimate. Also, only the revenue estimate is subject to wide and seemingly unpredictable price swings, in this case in the metals market (as discussed in Appendix D; and see Chapter Six for a discussion of the influence of changes in this market).

DOMESTIC RECYCLING COST MODEL

We assembled the calculations of dismantling cost, revenues from the sale of scrap and reusable materials, towing cost, and storage cost into a full model that calculates the total cost of a domestic recycling program. (See Appendix E for a summary of input factors.) We anticipate that if such a program were initiated, the experience gained through the repetitive work could lead to cost reductions. The PSNS advised us that it was able to achieve a 20 percent overall cost reduction during the first 10 years of its nuclear-powered vessel-recycling

program. This experience corresponds to a 95 percent learning curve and is typical of heavy-industry low-rate production processes. If such savings were realized, the last ship at the end of the 20-year program would cost about 72 percent as much to dismantle as the first ship, in constant dollars. However, the PSNS savings were nearly overcome by the costs associated with growing environmental requirements, with the result that the total PSNS dismantling cost per ton of ship has changed little over the years. If other ship recyclers learn from the PSNS experience, they may be able to avoid the cost growth and, through innovation in the recycling process, experience the 95 percent learning curve.

Table 3.9 gives the baseline inputs to the model. Note that these include a 0.5 percent aging factor, as was used in the long-term storage option (see Chapter Two). Because the recycling program is to extend over 20 years and involves a continually decreasing number of ships during that period, the aging factor's effect on total cost is very small and within the rounding error.

Based on these inputs, we estimate that the baseline cost for domestic recycling of the 358 inactive Navy and MARAD ships will be about $1.9 billion in undiscounted FY00 dollars, or $1.4 billion in discounted dollars. The best case uses a 90 percent learning curve, the lower end of the error envelopes for both labor costs (-30 percent) and ship complexity (-16 percent), and a scrap price 50 percent above the October 2000 market value. The result is a best-case cost estimate of $680 million in undiscounted FY00 dollars, or $510 million discounted. The worst case assumes a flat learning curve, the upper end of the error envelopes for both labor costs and ship complexity, and a 50 percent decline in

Table 3.9

Baseline Inputs for Domestic Recycling Cost Model

Towing cost ($/mile of tow distance)	224
Outfitting cost ($/ship per tow)	100,000
Average recycle tow distance (miles/ship)	955
Average dismantling cost ($/ton)	863
Navy ship scrap metal and salable parts ($/ton)	88
MARAD ship scrap metal and salable parts ($/ton)	64
Navy annual O&M per ship designated for scrap	57,000
MARAD annual O&M per ship designated for scrap	20,000
Weighted average annual storage O&M per ship designated for scrap	33,431
Annual storage O&M aging factor (%/year)	0.5
Discount factor (decimal) for discounted cost calculation	0.041
Recycle improvement curve slope (decimal) (log-linear unit)	0.95
Number of recycling sites	4

scrap price. The result in this case is $3.6 billion in undiscounted FY00 dollars, or $2.6 billion discounted.

NAVY AND MARAD BUDGET REQUIREMENTS

Based on the average program cost, the 20-year program will require about $125 million in the first year and will follow the trend shown in Figure 3.3.

Estimates of the total cost of a domestic recycling program depend in part on which agency originated the ship and which agency is the ship's current custodian. These considerations are necessary for two reasons: Navy-origin ships contain more scrap value than MARAD-origin ships do, and it costs more to store a ship at a Navy facility than at a MARAD facility. However, to determine how much of the cost of the domestic recycling program each agency will have to bear, we must consider who holds title to these ships.

Of the 358 ships in the inventory, the Navy now holds title to 147 ships adding to 1.2 million LSW tons. MARAD holds title to 211 ships adding to 1.6 million LSW tons (or about 56 percent of the total). Of the 147 Navy-title ships, 47 are amphibious warfare or auxiliary ships totaling 395,000 LSW tons. Title to these ships could be transferred to MARAD in the future, which would give MARAD title to 258 of the 358 ships and make it responsible for 1.9 million (about 70 percent) of the 2.8 million LSW tons to be disposed of.

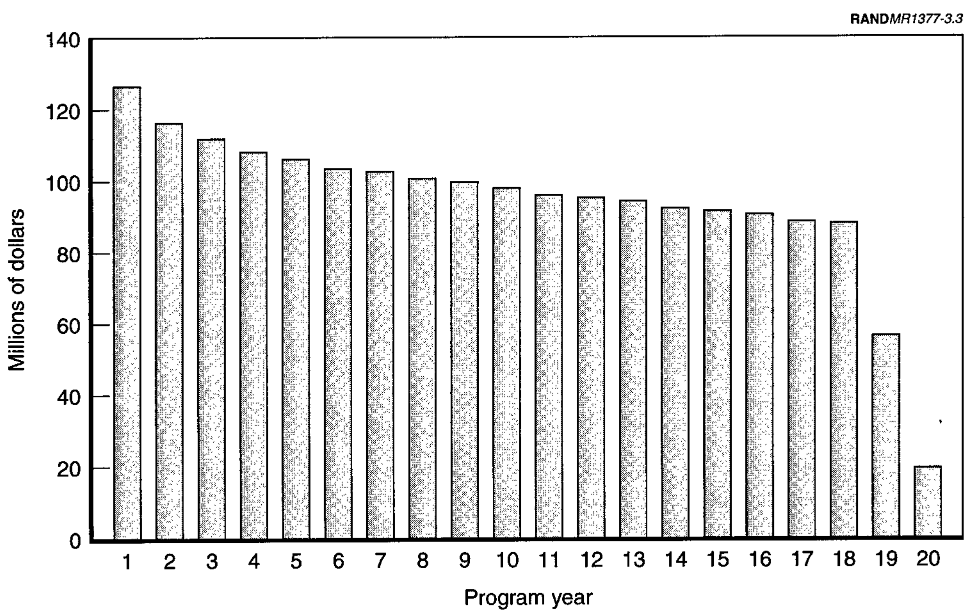

Figure 3.3—Annual Budget for Domestic Recycling

Such a title transfer would have a large impact on the two agencies' respective budgets for domestic recycling. Figure 3.4 shows, for the baseline cost estimate, the two agencies' annual domestic recycling budgets (in constant FY00 dollars). Figure 3.5 does the same but with the 47 transfers.

The ultimate cost of the domestic recycling option cannot be predicted any better than to within the range noted above. Dismantling costs and the learning curve are clearly important. In the Navy's second round of its SDP awards in late 2000, the bids of the three successful contractors ranged from much lower to slightly higher than the first-round bids. All of the first-round contracts experienced notable cost growth above their bid prices—as high as 72 percent. The ultimate cost per ton for the second round is not yet known. Additionally, the SS *Builder* experience suggests a lower cost, at least for merchant ships. The $0.7 to $3.6 billion range we provide is very wide, emphasizing the need to place long-term contracts with experienced ship recycling firms in order to maximize the learning curve and carefully monitor progress for cost containment.

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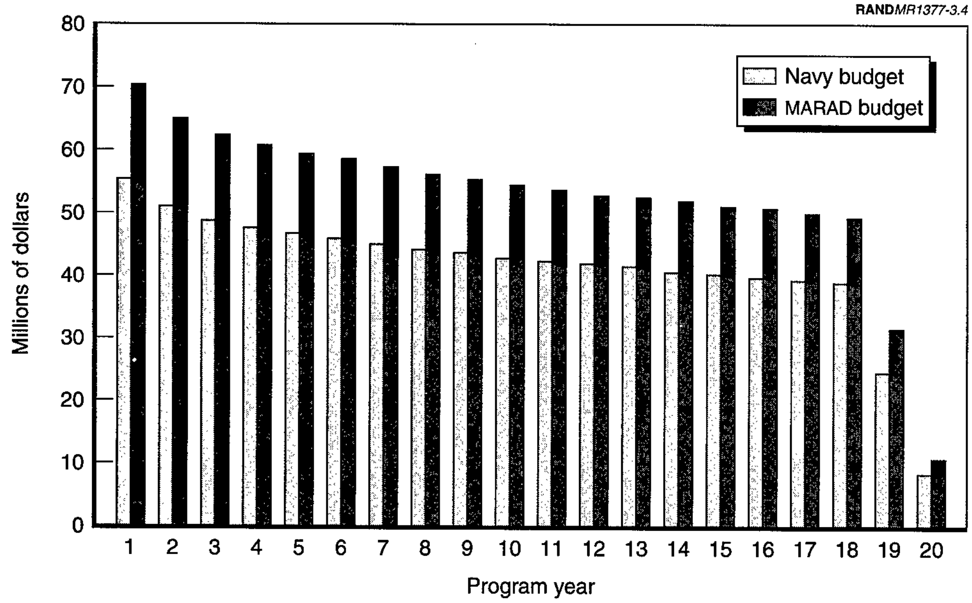

Figure 3.4—Annual Navy and MARAD Budgets for Domestic Recycling, Without Additional Title Transfers

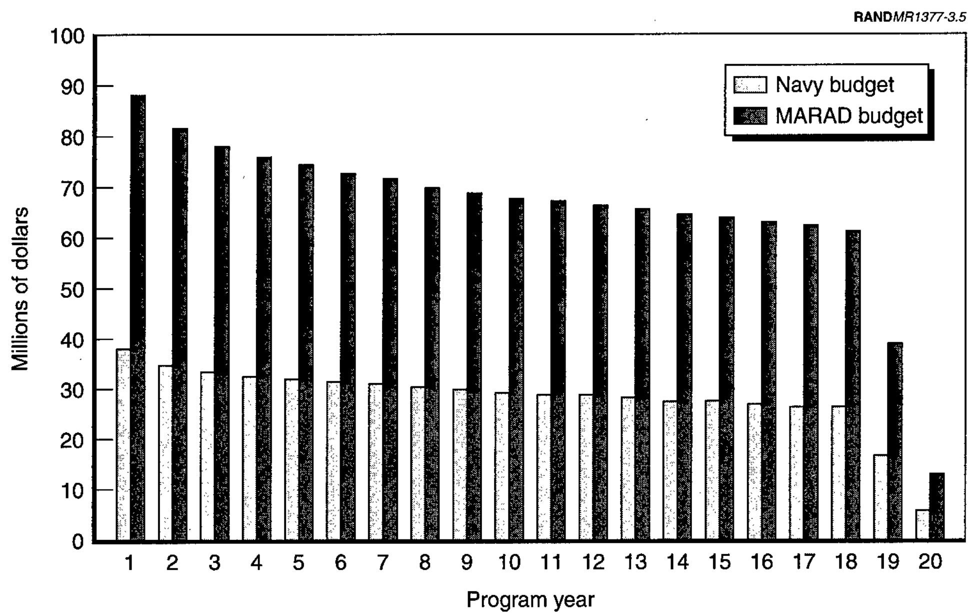

Figure 3.5—Annual Navy and MARAD Budgets for Domestic Recycling, With Additional Title Transfers

CONCLUSIONS

Domestic recycling of all 358 ships in the Navy and MARAD inactive fleet is practical but expensive. A 20-year program using four recycling contractors, each recycling between 30,000 and 40,000 LSW tons per year, will do the job and is well within the industrial capability of the U.S. maritime industry. The total cost of such a program will be about $1.9 billion in constant FY00 undiscounted dollars, although this cost could range from as little as $0.7 billion to as much as $3.6 billion. The annual cost to the Navy and MARAD combined will be about $125 million in the first year of the program according to our baseline cost estimate. How much of that cost must come from each agency's budget depends on whether titles to additional Navy ships are transferred to MARAD. With titles to the 358 ships as they presently stand, MARAD's budget for the domestic recycling option will begin at about $70 million per year in the early years, the Navy's at about $55 million. If the Navy transfers title to all 47 of its amphibious warfare and auxiliary ships to MARAD, MARAD's budget for this option will rise to about $88 million per year in the first year, and the Navy's will fall to about $38 million. Transfer or no transfer, however, careful monitoring of the recycling contractors will be needed to ensure that costs do not balloon above these levels.

Chapter Four

OVERSEAS RECYCLING

Overseas recycling was once a major form of disposal for U.S. government vessels and could become so again. The cost to the Navy to recycle all 358 vessels in the inactive fleet overseas would range from a small net gain to a cost of $170 million in constant FY00 undiscounted dollars. However, overseas recycling activities are in a state of strong flux because of short-term economic pressures and long-term environmental and safety pressures. Established industries in India and Turkey appear to be in decline because of these pressures, and their primary competition, China, has not yet shown an increase in recycling activities in the reported literature and data. U.S. regulations on the export of polychlorinated biphenyls (PCBs) must be amended before export of ships containing residues of this pollutant can resume. And foreign representatives to the Basel Convention on the Transboundary Movement of Hazardous Wastes want Convention restrictions to be applied to the trade in ships for recycling. If they are successful, the cost of a foreign recycling program will increase.

THE INTERNATIONAL SHIP RECYCLING INDUSTRY

Ship recycling is an international business. Conducted largely in less-developed countries, it is an integral and inseparable part of the shipping business. For as long as ships have existed, "shipbreaking," also known as "ship scrapping" (two ancient terms recently replaced by the more accurate "ship recycling"), has been the way ships end their lives if they are not lost at sea.[1]

The formula for deciding whether a ship lives or dies has historically been strictly economic. If after accounting for expected profits, the cost to keep a ship in service exceeds the ship's value to a recycler, the owner sells the ship to the recycler, who then reduces the ship to parts and scrap and sells them. This

[1]The number of ships lost at sea varies from about 150 to 300 per year. Most are small fishing boats averaging about 2,500 GRT each, or about 1,000 LSW tons each. From 600 to 1,100 ships of all sizes are recycled each year. These average about 13,000 GRT each, or about 5,100 LSW tons each.

formula held until very recently. In the 18th century, for example, ships were sold to a breaker for recovery of spars, firewood, and iron and brass parts for continued use in new ships or for remelting. Old lines were shredded by the many hands in poor houses to make oakum for caulking the seams of new ships. Everything was reused in some way. The economics of the system were very straightforward: The owner received money for his ship; the breaker received enough money for his scrap to pay his expenses and make a profit. The formula still holds in Bangladesh, China, India, and Pakistan because of very low labor rates and relatively few environmental, health, and safety regulations. In some developed countries, such as Turkey and Spain, the formula is being stressed by rising labor costs but still functions. In the United States, however, a once functioning ship recycling industry is virtually dead, a victim of the rising cost of doing business and falling and erratic scrap prices.

The usual pattern in the international ship recycling trade is for the owner to sell his ship to the recycling yard or, even more common, to sell his recycling rights to a so-called cash buyer, who then resells them to a recycling yard and arranges for the ship's delivery. Some ships are delivered to the recycler under tow, but most arrive under their own power.

The supply of ships for recycling is subject to both long-term and short-term pressures. Long term, merchant ships last approximately 25 years. While there are many exceptions, notably ships serving in the fresh water of the Great Lakes, most merchant ships cannot be maintained economically in service beyond 25 years. Other long-term pressures include requirements of the Oil Pollution Act of 1990 mandating replacement of single-bottom oil cargo ships within the next decade and the obsolescence of general cargo ships brought about by container ships. These long-term pressures suggest an adequate supply of ships, but short-term pressures are currently dominating the market. At this writing, there is a dearth of ships available for recycling because high freight rates are encouraging ship owners to keep their vessels in service despite their age. This situation could quickly change in a few weeks or months, however. The outcome at present is that the recycling rate does not exactly match the construction rate but comes very close.

Because of these variations, the ship recycling business must be structured to accommodate wide variations in the supply. In practice, this aspect of the business makes recycling more suited for less-developed countries, where labor is cheap and little if any expensive long-lived infrastructure is needed. Some developed countries are more suited for different reasons, such as their closeness to ship sources and ship product markets. Ship recycling has been performed in 79 nations over the past 10 years. India and Pakistan currently dominate the business, along with such lesser actors as China, Turkey, and Bangladesh.

Three Potential Recyclers for U.S. Ships

India. India has the world's largest ship recycling industry. In 1998, Indian yards accounted for 370 of the 888 vessels recycled that year, or 41 percent.[2] Figures 4.1 and 4.2 show the scale of Indian ship recycling in annual number of ships and annual GRT of shipping, respectively.

Ship recycling is performed in four areas of India: Alang, on the west coast in the state of Gujarat; Sachana, also in Gujarat; Bombay, to the south of Alang; and Calcutta, on the northeast coast. Indian ship recycling practices vary depending on the yard and include recycling from dry docks, alongside slips, and from tidal flats. By far, the largest yards are at Alang, on broad hard-clay tidal flats where the tides vary up to 30 feet. Each ship recycler at Alang is assigned a length of shoreline where ships are beached and recycled. These approximately 180 "plots" recycle about 350 ships per year, totaling as much as 3,000,000 metric tons LSW in recent years. Most ships arriving at Alang are driven onto the beach at high tide under their own power. As the ships are broken, the ever-lighter remainder is drawn closer to shore by winches (often recovered from

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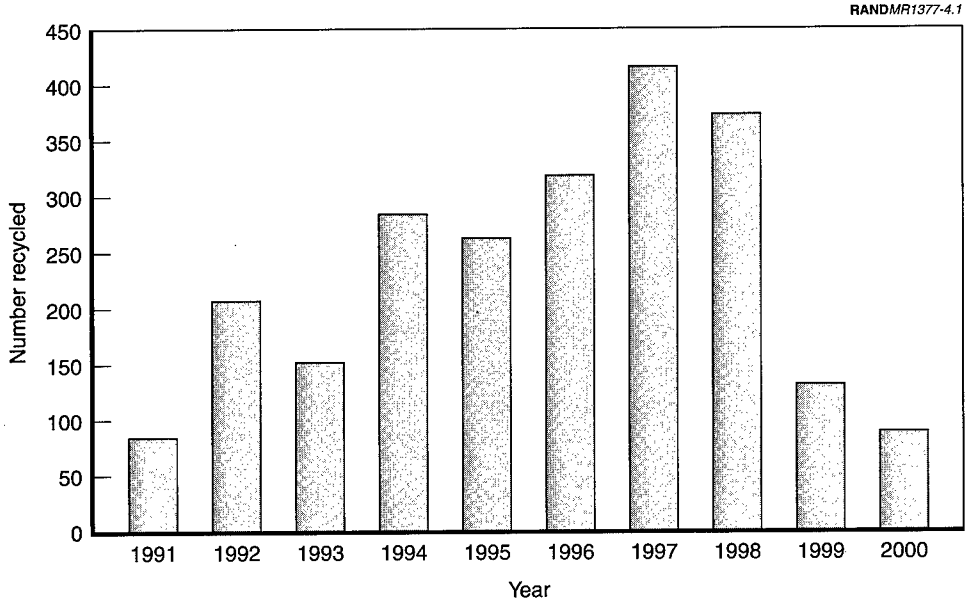
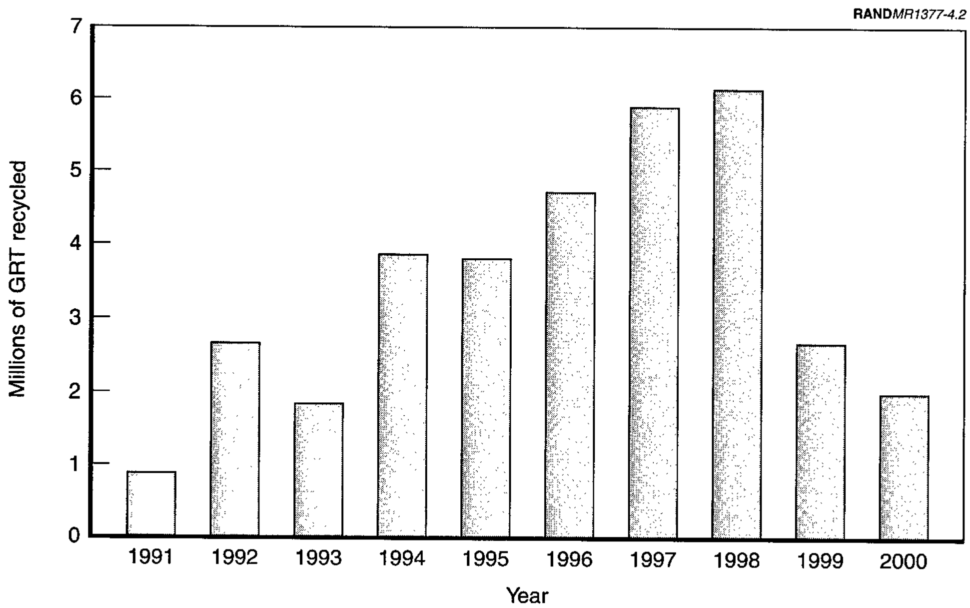


SOURCE: Lloyd's Demolition Database dated October 2000.

Figure 4.1—Indian Recycling, by Number of Ships

[2]India, Pakistan, Bangladesh and China together accounted for over 80 percent of all ship recycling from 1989 to 1998.



SOURCE: Lloyd's Demolition Database dated October 2000.

Figure 4.2—Indian Recycling, by GRT

earlier recycling jobs) fixed on-shore. Winches also serve to bring ashore large chunks of the ship cut free by the shipside work party. Once ashore, the chunks are reduced to plates and sections weighing no more than about 400 pounds, the limit that can be lifted onto a truck by manpower. Some recovered metals are sent to rerolling mills where metal plates are rerolled into reinforcing bar for concrete construction, metal roofing, or other plate or sheet products. Others are sent to remelting furnaces, where new products are fashioned. Many reusable parts are recovered and sold through local dealers adjacent to the Alang yard. Table 4.1 shows the types and amounts of materials, in percentage of total LSW, recovered from various ships recycled at Alang in recent years.[3]

During the last few years of a merchant ship's life, little attention is paid to maintaining its hull. Therefore, most ships are very rusty when presented to recyclers. In fact, most of the lost weight shown in the last column in Table 4.1 is due to rust, except in the case of naval ships. Naval ships have more nonrust waste than other ships because of their military electronic and electrical systems, which have no reuse potential in India. At an Indian recycling yard,

[3]Ferrous Scrap Committee, Government of India, *Comprehensive Environmental Impact Assessment and Environmental Management Plan*, August 1997.

Table 4.1

Types and Amounts of Materials Recovered by Alang Ship Recycling (in percentage of LSW)

Type of Vessel	Reroll Plate	Melting Scrap	Cast Iron	Nonferrous Metals	Machinery	Wood and Misc.	Weight Lost
General cargo	56–70	10	2–5	1	4–8	5	9–15
Bulk carrier	61–71	8–10	2–3	1	2–5	1–5	10–16
Ore carrier	62–69	10	3	1	3–5	5	10–16
Passenger	44–58	10	5	1–2	10–15	5–7	11–17
Oil tanker	72–81	5–7	2–3	1–2	1–2	1–2	10–12
Ore bulk oil carrier	66–75	8–10	3	1	1–6	1–2	10–13
Naval ship	53–67	10	2–6	1–2	4–6	1–2	15–22
Container ship	63–67	10	3–4	1	5	5	10–13
Fishing/trawler or factory	47–67	10	3–8	1–2	2–10	5	12–18

only 2 to 3 percent of LSW is waste. It is dumped as landfill in adjacent areas and sometimes it is used to harden the soil of the recycling plots.

For the most part, ships arrive in India for recycling fully outfitted and operating under their own power, thereby providing many valuable materials that can be and are recovered for reuse. Overall, 70 different species of materials other than scrap steel, reroll plate, and fabricated steel products are recovered from ships. Even materials that in fully developed countries would be waste are recovered for reuse by Indian recyclers. In India, the sale of such materials—even at very low prices ranging from a penny to a nickel per pound—is profitable.

Although ship recycling in India is a successful business, it remains difficult and highly competitive, with a close balance between costs and revenues. Table 4.2 illustrates the cost and revenue stream for a typical recycling project in the Indian market.[4]

Table 4.3 illustrates the percentage of the total market value represented by the different species recovered in a recycling project.[5] These are average figures. The larger the ship, the more reroll steel recovered. (See Table 4.1 for comparable information by ship type in terms of percentage of LSW.)

[4]Ferrous Scrap Committee, Ministry of Steel, Government of India, *Shipbreaking in India, A Roadmap for Future Development*, undated (circa spring 1999).

[5]Ibid.

Table 4.2

Costs and Revenues for Average Ship Recycling Project in India

	Amount per Metric Ton of LSW	
	Rupees	US$[a]
Cost of vessel	4,916	109
Customs duty	246	5.5
Customs duty surcharge	25	0.6
Additional custom duty (VAT)	829	18
Port charges	600	13
Total cost of vessel	6,616	147
Interest on investment	300	7
Misc. banking charges	300	7
Dismantling labor	500	11
Torch oxygen and fuel	400	9
Crane for hire	50	1
Security/supervisor	200	4
Central excise duty	150	3
Total	8,517	189
Sale of recovered equipment and materials	9,400	209
Operating profit	884	20

[a]A conversion rate of Rs45/US$ was used.

Many variables can quickly alter the narrow balance between Indian ship recycling costs and revenues. Ship cost to the recycler is erratic, varying year to year from $110 to $185 per ton depending on ship type and the play of the market between buyers and sellers. Government taxes and fees add to about 20 percent of the recycler's costs, making government policy an important factor. The price a recycler receives for reroll or remelt steel depends on the market for competing sources.[6] The Indian primary steel industry is burdened with many Soviet-design mills that are inefficient in terms of energy and labor burden; as this industry modernizes, the value of scrap steel in India will fall. And there is international pressure to improve environmental, safety, and health practices in the ship recycling industry at added cost to recyclers. Thus, many different forces can affect the current balance.

Note that there are no environmental, safety, and health costs shown in Table 4.2. This is not from ignorance. Indian recyclers are well aware of the safety and environmental issues common to ship recycling. In a study for the Indian

[6]In contrast to India, the United States has no market for reroll plate. All steel must be sold for remelting, and remelting scrap in the United States commands less than half the price of reroll plate in India.

Table 4.3

Percentage of Total Revenue from Species Recovered in Indian Ship Recycling

Species	Average Percentage of Total Revenue
Reroll steel	61
Machinery and equipment	8[a]
Cast iron	7
Nonferrous metals	7
Remelt steel	6
Shafting	6
Pipes and castings	4
Wood, nonmetals, and misc.	1[b]

[a]Machinery and equipment can be worth more if they are removed by the buyer to ensure they remain in good shape.

[b]This 1 percent hosts a substantial cottage industry of small shops along the coast of Alang. These shops sell brass goods, windows, furniture, and all of the assorted other products that do not feed heavy industry.

government, Metallurgical & Engineering Consultants (India) Limited found that there are between 250 and 800 kg of PCBs in paint on a typical merchant ship, as well as 20 to 30 kg of lead. On average, between 4,000 and 5,000 kg of asbestos insulation is also present, along with an additional 50 tons as joiner bulkheads.[7] Paint is left on the steel plates when they are removed and sent for rerolling or remelting. Asbestos products are sold for reuse, as are PCB oils from the ship's electric and hydraulic machinery. The Alang yards annually generate about 2,400 metric tons of hazardous wastes such as oil sludge and paint chips.[8] In the past, all wastes, hazardous or not, were dumped in the sea or in nearby low-lying areas. The Indian government is now placing storage facilities and incinerators at recycling yards to contain and burn some of these wastes. These practices are reported to be consistent with Indian law. These actions will undoubtedly alter the balance sheet but by how much is not yet reported.

Labor constitutes just less than 6 percent of the total cost of recycling a ship at an Indian yard. Laborers earn anywhere from Rs100 for helpers to about Rs150 for torch cutters for a 10-hour day, six days per week, which is equivalent to earning $2 to $3 per day in the United States. While this is certainly a dismal

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[7]B. D. Ghosh, "Shipbreaking Industry in India: Present Status and Future Prospects," 1999, included as Appendix B in Ferrous Scrap Committee, Ministry of Steel, Government of India, *Shipbreaking in India, A Roadmap for Future Development*, undated (circa spring 1999).

[8]Keyur Shah, *Shipbreaking Industry—Exigency for Environmentally Sound Management Practices*, Central Pollution Control Board, Government of India, February 2000.

wage by U.S. standards, it is competitive in India for unskilled and semiskilled labor. Workers at the Alang yards generally are not locals from Gujarat State but come from distant impoverished States such as Uttar Pradesh in the north. Safety standards exist, but accidents are frequent. Alang has oscillated between 7 and 12 fatal accidents (where one or more people were killed) per 10,000 workers per year during the past three years. Fire and explosions are the most common types of accidents, followed by suffocation (in tanks that were not gas-freed as required by Indian law) and then falls or being struck by falling objects. Alang's accident rate compares to the rate of 5 to 7 fatal accidents per 10,000 workers per year in other heavy manufacturing industries in India. In early 2000, the Indian government began worker safety education and renewed safety enforcement to try to reduce the accident rate at ship recyclers.[9]

At present, India remains a leader in ship recycling but is under heavy pressure. Environmental conditions at the Indian yards remain of concern. In an article in India's leading newspaper, Kingshuk Nag heavily criticized the shipbreaking industry, noting that it may be in a phase-out stage and is a "killer and environmentally degrading industry rolled into one."[10] The article went on to report that the Gujarat Maritime Board (GMB), the responsible government agency, had found widespread ignorance among workers about basic safety requirements and widespread environmental problems in the area. Along with environment and safety problems, the industry is also threatened by the current high price of ships for recycling (about US$175 per ton), the relatively high price of Indian labor compared to labor elsewhere in Asia, and strong competition from ultra-large new mechanized breaking yards in China.

China. China is building modern graving dock facilities for recycling very large crude carriers and ultra-large crude carriers near Shanghai. These facilities are being built under arrangements with some major shipping companies (including The Peninsular & Orient Steam Navigation Company and British Petroleum) that will guarantee a steady supply of ships for recycling. Many ship owners are under public scrutiny in their homelands for being the source of alleged misery in India (a charge forcefully refuted by Indian businessmen and workers). In return for promising the Chinese firms ships, the ship owners have been promised good environmental controls and safe working conditions for the Chinese workers and a good price for their ships. Whether these plans will come to frui-

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[9]The ship recycling industry in Pakistan is very similar. The price of reroll plate is higher than in India, worker wages are lower, and the work day is longer (12 hours instead of 10), but government taxes and fees are higher.

[10]Kingshuk Nag, "Alang: Shape Up or Ship Out," *Times of India*, November 3, 2000.

tion is unknown. According to Lloyd's, there is little current evidence that the Chinese industry is growing (see Figures 4.3 and 4.4).[11]

Turkey. Ship recycling in Turkey was conducted during the past decade by up to 28 firms in the town of Aliaga, which is on the Aegean Sea on Turkey's west coast. During those 10 years, as many as 3,000 workers were employed at any one time. The yards claim to be able to recycle nearly every size of ship, including ultra-large crude carriers, but the largest ship to date, recycled in 1997, weighed 26,400 GRT (or less than 13,000 LSW tons). Figures 4.5 and 4.6 show the recycling history of the Turkish industry over the past 10 years by number of ships and ship GRT.[12] Most of the ships were from Russia, Ukraine, or Greece.

Note that the numbers and GRTs seem to indicate that the industry is in decline. We have been advised that the Turkish industry faces the same safety and environment pressures being faced by the industry throughout the world and has also been affected by the high price and dearth of ships presently available for recycling.

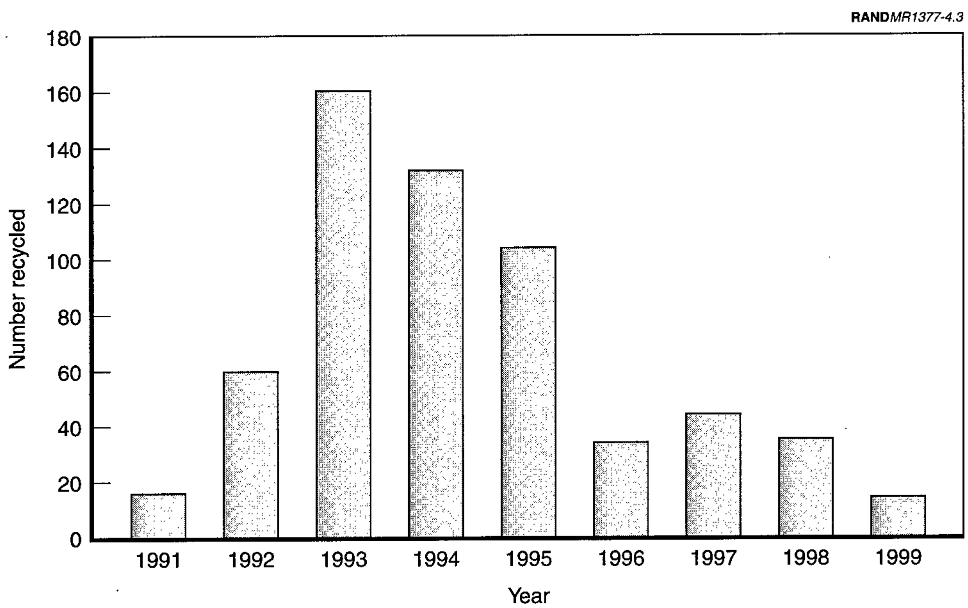

Figure 4.3—Chinese Ship Recycling, by Number of Ships

[11]Lloyd's Maritime Information Services, "Demolition Database," October 2000. Note that the database does not include data on Chinese recycling for the year 2000.

[12]Lloyd's Maritime Information Services, "Demolition Database."

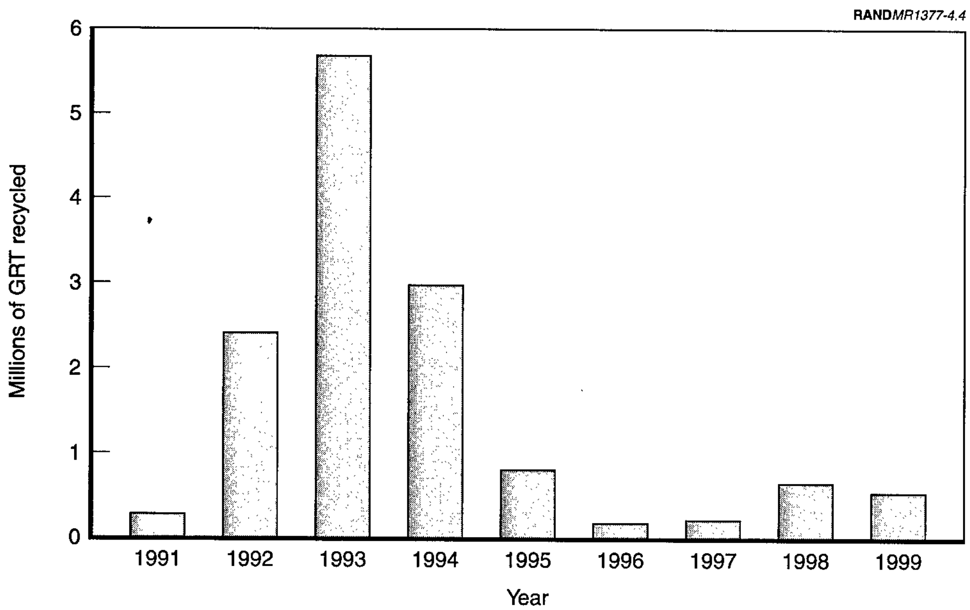

Figure 4.4—Chinese Ship Recycling, by GRT Recycled

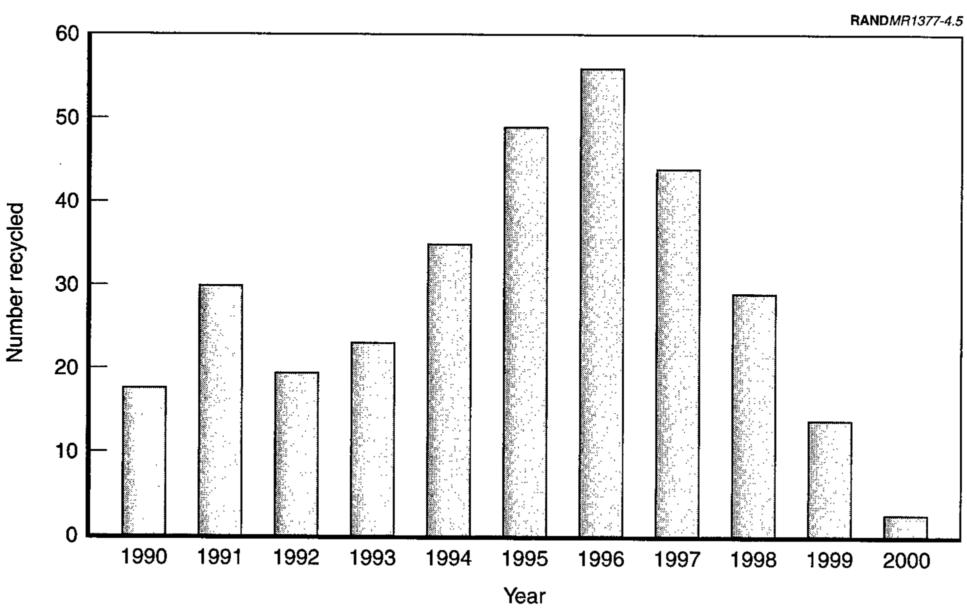

Figure 4.5—Turkish Recycling, by Number of Ships

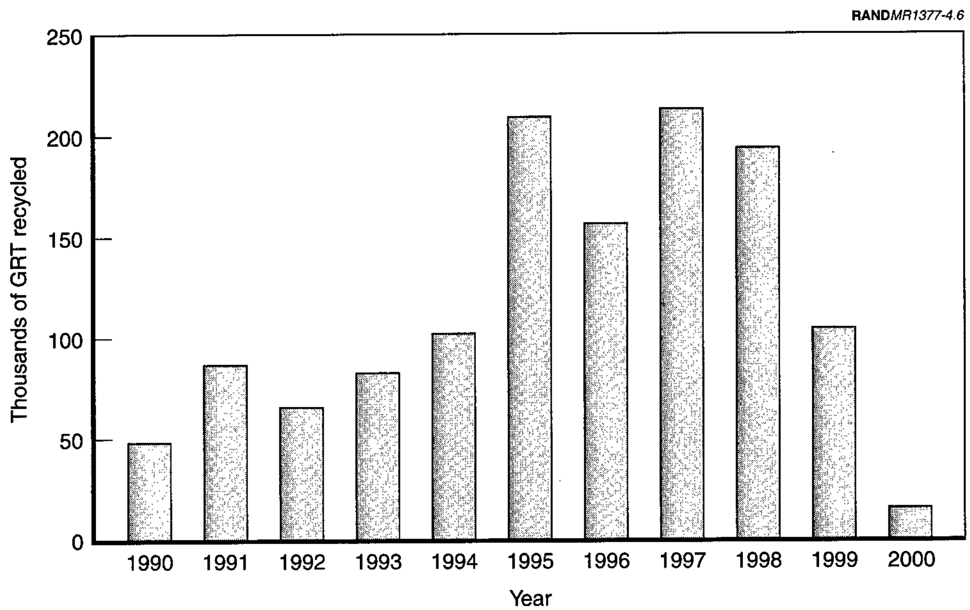

Figure 4.6—Turkish Recycling, by GRT Recycled

We attempted to engage the Turkish industry but found no yard or industry representative willing to provide information. Anecdotal information from Turkish contacts suggests that environmental problems are causing the decline. Nonetheless, we include the Turkish option in our analysis because its past capacity suggests that it would have the facilities needed to handle the work.

The European Naval Role in the Ship Recycling Industry

The European navies individually play only a marginal role in feeding the international ship recycling industry. The major reason for this small role is that these navies are much smaller than their U.S. counterpart. Together they deploy only six small aircraft carriers, including four VSTOL/helicopter carriers, compared to the U.S. active inventory of 12 very large aircraft carriers. European members of NATO operate a total of 225 principal surface combatants (frigates or larger warships); the U.S. inventory is 130. Thus, the individual European navies simply lack the raw numbers in terms of ships and tonnage to contribute much to the international supply of ships for recycling.

Current Ship Disposal Practices. The European navies currently dispose of their ships in three main ways, the first of which is by selling them to other navies in the developing world. They have been very successful at this. For example, when the Royal Netherlands Navy downsized from 24 to 14 frigates, it

sold all 10 for use by other navies.[13] Relatively few ships end up sold for scrap by their original owners, and those that are sold for scrap typically are smaller craft such as mine hunters. This reflects in part Europe's growing awareness of environmental considerations and many countries' efforts to implement the Basel Convention, in which the European participants pledged not to ship hazardous wastes from Organization for Economic Cooperation and Development (OECD) countries to non-OECD countries. Many Europeans are considering whether this obligation places restrictions on the long-standing practice of sending ships to Asia for recycling.[14]

Second, several of the European navies maintain some ships in reserve/long-term storage status. This status typically involves preserving low density but infrequently needed capabilities by storing selected ships in a condition that allows them to be made fully operational within 6 months if required.

Third, the British and Germans have become very good at ship conversions that often include radical alterations in a ship's architecture, thereby giving the ship a second life as a virtually new type of ship. Britain currently holds 40 percent of the world market share in ship conversions, accounting for business worth 1.4 billion pounds sterling.[15] Many Royal Navy and Royal Fleet Auxiliary vessels undergo conversion. The overall result is that vessels that otherwise would be obsolescent in their original class undergo conversion to make them suitable for other duties.

Table 4.4 offers a snapshot of the ship disposals of the British Royal Navy, French Navy, and German *Kriegsmarine* between 1997 and 1999. The data were compiled from the U.S. Naval Institute's "Periscope" database and the UN arms transfer reports maintained pursuant to the Transparency in Armaments Agreement. We estimate that the transactions shown in the table account for approximately 534,906 tons, only a fraction of which will find its way directly to the recycling industry since most of it represents transfers of ships to other naval forces. Of course, secondary users eventually dispose of ships by means we have not researched. We judge it likely, however, that the ships eventually are recycled. If all are recycled, they represent less than 1 percent of the 68 million tons the U.S. Interagency Panel on Ship Recycling estimated would be recycled over a 10-year period.[16]

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[13]Information provided by the Navy Procurement Office, Royal Netherlands Embassy, Washington, DC.

[14]Telephone interview with Anna Tschursin, EPA, November 26, 2000.

[15]Lloyd's Register of Shipping and EU Commerce at http://www.ssa.org.uk/news.htm.

[16]*Report of the Interagency Panel on Ship Scrapping*, April 1998, at http://www.denix.osd.mil/denix/Public/News/OSD/Ships/ Final/final.html.

Table 4.4

Disposal of Ships by British, French, and German Navies, 1997–1999

No. of Vessels	Type of Vessel	Form of Disposal
Britain		
6	Type 21 frigate	Sold to Pakistan
4	Type 22 frigate	Sold to Brazil
1	Leander class frigate	Sold to India
1	Leander class frigate	Sold to Chile
4	River class MCMV	Sold to Bangladesh[a]
3	River class MCMV	Sold to Brazil
1	Fleet tanker	Sold to Indonesia
1	Fleet tanker	Sold to Portugal
3	Peacock class PC	Sold to Philippines
France		
1	Agosta class sub	Withdrawn
2	Agosta class sub	Placed in reserve
1	CV *Clemenceau*	Retired
1	CV *Foch*	Placed in reserve
1	Type F65 destroyer	Decommissioned
1	Rance class tender	Decommissioned
Germany		
4	Tiger class Type 148 frigate	Sold to Chile
5	Frauenlob class Type 394 inshore MCM	Withdrawn

[a]Since Bangladesh is an important ship recycling country, we looked to see whether these ships entered the Bangladeshi navy or were scrapped. It appears they entered naval service.

Potential Future Disposal Practices. Two other disposal practices—recycling and reefing (i.e., sinking ships to create artificial reefs)—are not yet major disposal options for European naval ships, although there is some evidence that reefing may be becoming an attractive option.[17] The Netherlands will conduct a sinking experiment in the next few months.[18]

The future of European reefing as a means for disposing of naval ships rests in part on whether European standards for preparing a ship for reefing prove to be cost-effective. The European Union continues to investigate environmentally sound ship recycling practices in hopes of recycling European ships at home, thereby providing more jobs for shipyards while also ending the export of hazardous materials to the developing world.[19] If it proves more economical to

[17]Canada has already reefed several warships. See Chapter Five for a discussion.

[18]According to the Netherlands Ministry of Transportation, Europe is currently observing a policy of not sinking ships for artificial reefs until the consequences of doing so are fully understood.

[19]A second ship recycling summit is slated for June 2001. It is to be hosted by Mareforum, a Netherlands-based policy advocacy firm.

prepare a ship for reefing than to recycle it, reefing may become a more common practice. Given that few naval ships are too old to be sold to other navies, however, the number of European ships available for reefing would still be small: probably fewer than 10 per year.

TOWING SHIPS TO OVERSEAS RECYCLING SITES

A fundamental assumption in all overseas ship recycling operations that we reviewed is that the ship owner or broker will deliver the ship to the recycling site. This is most often done by driving the ship to the site, including onto the beach at sites such as Alang, India, at the conclusion of the ship's last merchant journey. Nearly all 358 ships in the inventory (see Appendix A, Table A.2) are in long-term storage and cannot easily be made operable. We did not examine the costs to restore such ships to operating condition and to steam them to a distant recycling site. However, based on our observation that both the Navy and MARAD routinely tow inactive ships rather than make them operable, we concluded that the cost of making them operable would be very high. We therefore assume that should overseas recycling be chosen as the disposal option for part or all of the inventory, towing will be the method used to move ships to the recycler.

To estimate the number and location of ships to be towed, we used the data in Appendix A, Table A.2 (see Appendix A for the derivation of this inventory). From this information, we assembled estimates of towing cost per LSW ton, as shown in Table 4.5. Included in the table are the distance between the selected ports (always Suisun Bay on the U.S. West Coast and Philadelphia on the U.S. East Coast) and the calculated towing cost per mile.

Revenues from the sale of an old ship vary significantly. The Lloyd's demolition database has price entries for over 1,900 of the 7,000 ships recycled from 1990 to 2000.[20] Prices range from $27 to $274 per LSW ton and average $161 per LSW ton. The highest prices were seen in 1990 and were not seen again for the remainder of the decade. In late 2000, prices for the year had so far varied from $126 to $171 per ton in the Lloyd's database, but the trade literature reported prices as high as $180 per ton.[21] Ship price depends on ship type. For example, dry cargo vessels command a lower price than tankers do because more labor is needed to disassemble their more complex internal structures. Such ships were priced at $165 per LSW ton in 1995 but fell to $110 per LSW ton by 1998. Based on all of this pricing information, we selected a price range of $100 to $150 per LSW ton for recycling U.S. ships overseas. We assume for this option that

[20]Lloyd's Maritime Information Services, "Demolition Database."

[21]Lloyd's List, Friday, November 17, 2000.

Table 4.5

Towing Cost Estimates

From	Number of Ships	LSW Tons	Nautical Miles	$ per Ship	$ per LSW Ton	$ per Ship Mile
West Coast						
California	88	571,968				
Hawaii	21	113,422				
Washington	12	156,410				
Total west to Alang			10,461	2,057,000	296	197
Total west to Shanghai	121	841,800	5,513	1,181,500	170	214
Total west to Aliaga			13,853	2,654,400	382	192
East and Gulf Coast						
Pennsylvania	40	359,590				
Virginia	105	746,976				
Florida	6	2,685				
North Carolina	2	20,658				
Connecticut	1	2,485				
Rhode Island	1	54,600				
Alabama	2	13,950				
Texas	43	423,480				
Total East to Alang			8,310	1,722,250	212	207
Total East to Shanghai	200	1,624,424	11,726	2,355,700	290	201
Total East to Aliaga			5,140	1,181,500	145	230
Active or unspecified	37	305,946				
Total	358	2,772,170				

overseas recycling could be accomplished very quickly once a decision is made, surely in no more than 5 years. The interim storage costs for the dwindling fleet during this period will total about $23 million, or about $8 per ton on average.

Using these estimates, we arrived at the minimum and maximum net cost (towing plus storage minus sale price) to the U.S. government for an overseas recycling program. These costs are shown in Table 4.6.

The best-case net cost to the U.S. government thus is $3 per ton for East Coast ships recycled in Aliaga, Turkey, and sale proceeds of $150 per ton. The worst case is a net cost of $290 per LSW ton for West Coast ships recycled in Aliaga and sale proceeds of $100 per ton. The most advantageous situation is a combination: East Coast ships recycled in Aliaga ($3 to $53 per LSW ton) and West Coast ships recycled in Shanghai ($28 to $78 per LSW ton).

Of the 358 vessels requiring disposal, about 0.8 million tons lie in West Coast ship storage facilities, with the balance in East Coast facilities. Thus, for a five-year overseas recycling program that uses this assessment's optimum sites and includes the storage costs for the ships remaining during the period, the U.S.

Table 4.6

Minimum and Maximum Net Cost of Overseas Recycling Options ($ per LSW ton)

	Alang			Shanghai			Aliaga		
	Tow and Storage Cost	Max. Net Cost (@ $100)	Min. Net Cost (@ $150)	Tow and Storage Cost	Max. Net Cost (@ $100)	Min. Net Cost (@ $150)	Tow and Storage Cost	Max. Net Cost (@ $100)	Min. Net Cost (@ $150)
From East Coast	220	120	70	298	198	148	153	53	3
From West Coast	304	208	158	178	78	28	390	290	240

government would pay from about $28 million to $170 million depending on the revenue from ship sales. As discussed in Chapter Three, the Navy and MARAD will each manage the program costs for the ships to which they hold title. If no additional titles are transferred (47 could possibly be transferred from the Navy to MARAD—see Chapter Three, Table 3.5), MARAD will be responsible for about 56 percent of the total cost ($17 million to $94 million) of the overseas recycling program, and the Navy will be responsible for the rest. If the additional titles are transferred to MARAD, its share of the responsibility will increase to about 70 percent of the total cost ($20 million to $120 million).

Our towing cost estimates are conservatively high for the reasons noted above. Tandem tows, use of towing companies more conveniently located to the inactive fleet sites, use of overseas towing companies, and other actions could significantly reduce towing costs. In fact, towing cost savings of up to 40 percent can be expected. With such savings and favorable ship sale prices, an overseas ship recycling program might operate at a profit. This is not surprising. Until the U.S. government stopped overseas transfer of ships a few years ago, many government ships were disposed of at a profit to all parties concerned: the government, the ship brokers, and the ship recyclers.

IMPEDIMENTS TO OVERSEAS RECYCLING

During the 106th Congress, legislation was considered, but not passed, to direct the establishment of an overseas recycling program for Navy and MARAD ships. Congress considered such action because of the presumed low cost of this approach to the recycling issue, a presumption confirmed by this study. However, there are many impediments to such a program.

We note the following four impediments to restarting the export of Navy and MARAD ships for recycling:

1. The UN's International Maritime Organization (IMO) has been the traditional international regulator of ships and shipping. Within IMO and the UN's Basel Convention on Hazardous Wastes, there have been ongoing debates concerning the environmental aspects of ship recycling. In recent years, some have suggested that Basel should regulate trade in scrap ships under its rules—i.e., that ships destined for scrapping should be regulated under Basel as hazardous wastes. Many alternative requirements are also being aired, such as placing a tax on ship owners to fund environmental protection during recycling, requiring ships to be delivered for recycling free of hazards, and/or requiring ship owners to provide recyclers with a complete inventory of the hazardous materials aboard. Many private and international governmental parties are pushing for greater control of foreign ship recycling operations to reduce the safety hazards to workers and better protect the environment surrounding recycling locations. These parties are suggesting that ship owners should "clean" their ships before delivering them for recycling so that safety and environment hazards are reduced. Possible actions include cleaning of fuel and cargo tanks, removal of hazardous materials, and inspection and recording of remaining hazards so that the recycler can take appropriate actions. For many of the ships involved in this assessment—particularly those originating in the U.S. Navy—such actions have already been taken. We thus do not anticipate that the current push for cleaning ships before delivery will notably impact the range of estimates we have provided. None of the alternatives has yet become law. IMO and Basel have agreed that for the present IMO will continue to regulate ships in all circumstances on the seas and in ports, and Basel will regulate international transportation of wastes that ships generate during the process of recycling. A working group within Basel has been tasked to develop draft regulations for further discussion. The ultimate outcome of the discussions is uncertain but could, if in favor of Basel regulation of trade in ships for recycling, definitely increase the costs of a Navy-MARAD overseas recycling program and severely disrupt not only the current international ship recycling regimen but the current international shipping business as well.

2. U.S. regulations under the Toxic Substances Control Act, found at 40CFR760, place an absolute ban on the export of PCBs (see Appendix C). Since the discovery of PCBs in ships, the export of ships for recycling has been legally banned by this rule. Before an export program could begin, the export ban must be lifted.

3. An administrative ban on exporting U.S. Navy ships to overseas recyclers, issued by the Secretary of the Navy in 1997, is still in force. This ban applies only to ships to which the Navy still holds title, and therefore only to about one-third of the ships in the inactive fleet. There is no current administrative ban on the export of ships to which MARAD holds title; however, the existing Navy ban may pose problems for the agencies should an export program be established.

4. Impediments may arise from public perceptions of foreign labor conditions. Many parties, most notably Greenpeace, have severely criticized working conditions and environmental controls in Asian recycling yards as being severely wanting. Even though a U.S. Navy and MARAD ship recycling program would only represent a small fraction of the international recycling business, there is likely to be pressure from such sources to stop such a program.

CONCLUSIONS

The United States government once used overseas recycling to dispose of its ships and could do so again except for the many new and emerging impediments that stand in the way. The cost to the Navy to recycle all of the 358 ships in the inactive fleet overseas would range from a small net gain to a cost of $170 million in FY00 undiscounted dollars under current conditions. However, overseas recycling activities are in a state of strong flux because of short-term economic pressures and long-term environmental and safety pressures. Established industries in India and Turkey appear to be in decline because of these pressures, and the possible primary competition, China's recycling industry, has not yet shown an increase in its activities in the reported literature and data. U.S. regulations on export of PCBs must be amended before the United States can resume sending ships containing residues of this pollutant to overseas recyclers. And any restrictions on the international trade in ships for recycling that emerge from discussions now under way among representatives of the Basel Convention will increase the cost of foreign recycling and in some circumstances may prohibit the sale of ships.

Of the three options for ship disposal, overseas recycling costs the least. However, in our judgment, the impediments are so substantial as to make an overseas recycling program very unlikely to succeed. Absent direction from higher authority, we recommend that the Navy and MARAD not initiate an overseas recycling program.

Chapter Five

REEFING

Artificial reefs have been a part of man's history for all recorded time. About 2000 years ago, the ancient Greek geographer Strabo recorded that the ancient (to him) Persian kingdoms built reefs across the mouth of the Tigris River to obstruct the passage of marauding naval pirates from India, the Vikings of the time. Many ancient naval battles involved blockading harbors with artificial reefs. About 200 years before Strabo, the Roman historian Polybius recorded that the Romans built a reef across the mouth of the Carthaginian harbor of Lilybaeum in Sicily during the First Punic War to trap the powerful enemy ships within and assist in driving the Carthaginians from the island. In modern times, mines are usually used to blockade harbors, and artificial reefs are relegated to more-benign tasks.

The first documented artificial reef in the United States dates from 1830, when log huts were sunk off the coast of South Carolina to improve fishing. Since then, and until the latter part of the 20th century, most artificial reefs were built by ad hoc volunteer groups for the same reason—to improve fishing. Like the 1830 reef, 80 percent of the reefs constructed off U.S. coasts have used materials of opportunity: trees, rocks, shells, ships, barges, and in very recent years unwanted oil and gas recovery structures.[1] All such reef materials have had one common feature: they were free to the volunteers, or nearly so.

Only since the mid-1970s have engineered structures been used for artificial reefs, and even today they remain in the minority. Recent years have seen increased interest in using artificial reefs to replenish or replace depleted fishing grounds and to serve the relatively new activity of recreational scuba diving.[2] In a survey recently completed for this study, Atlantic and Gulf Coast state reef

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[1]Gulf States Marine Fisheries Commission, "Guidelines for Marine Artificial Reef Materials," No. 38, January 1997.

[2]Ibid., p. 55.

authorities reported that over 846 vessels have been used for reefs during the past 25 years—and that there is near-term demand for hundreds more.[3]

There are impediments to reef building with ships in U.S. territorial waters, however, all of which involve issues of cost and the environment. The Atlantic States Marine Fisheries Commission (ASMFC) reports that the reasons so few large U.S. government ships have been deployed as reefs are (1) lack of funds to prepare the ships, (2) uncertainties on how to handle pollutants such as PCBs and asbestos, (3) the question of state liability for the reef, and (4) unclear MARAD rules regarding ship availability.[4] The report voices no concerns specifically about the use of Navy ships, because Navy ships have not heretofore been available for reefs (other than Navy nonwarships transferred to MARAD upon their retirement).

We begin the rest of this chapter by discussing the demand for artificial reefs. We then describe the impediments to reefing programs, estimate the costs such programs would entail, and discuss the economic benefits that derive from artificial reefs.

THE DEMAND FOR ARTIFICIAL REEFS

In 1994, the ASMFC reported that at least 666 steel-hulled vessels had been sunk for reefs since 1974. Forty-one of these ships were donated to the states by MARAD pursuant to Public Law 92-402 of 1974, "The Liberty Ship Act," which was amended in 1984 by PL 98-623 to include ships other than Liberty ships. Although MARAD's 41 ships only amounted to 6 percent of the total, they constituted almost all of the 44 large ships sunk—i.e., those over 300 feet long. Nearly half of the 666 ships were very small fishing boats or tugboats no more than 75 feet long. Average ship size, then, was small, but the vessels were of many different types, including Navy landing craft, barges, dry docks, and different kinds of merchant ships. [5]

Reefs continue to be built with ships from a variety of sources. Florida and other states use ships from private or public sources, including on occasion a local Navy command. There is current demand among Atlantic and Gulf Coast states for over 540 ships just to meet needs for improved fish resources.[6]

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[3]This survey was conducted by Mel Bell, Department of Natural Resources, State of South Carolina, and Tom Maher, Florida's Division of Marine Fisheries, Summer 2000.

[4]Atlantic States Marine Fisheries Commission, "The Role of Vessels as Artificial Reef Material on the Atlantic and Gulf of Mexico Coasts of the United States," Special Report 38, December 1994, pp. 4 and 6.

[5]Ibid.

[6]Survey conducted by Mel Bell and Tom Maher, Summer 2000.

We broke the current demand for artificial reefs into three parts: demand for reefs for the promotion of marine life and commercial fish–related activities, demand for reefs for sport diving, and demand for reefs for other uses.

Artificial Reefs for Promotion of Marine Life and Fishing Purposes

Artificial reefs, whether from ships or other forms of solid materials, are generally accepted as beneficial to the increase of sea life in sandy or mud-bottom coastal areas. Ocean bottom areas that have no solid surfaces but have other features needed for life (such as proper salinity, light, and nutrition) are generally poor in marine life except for transiting species at certain times of the year. With an anchor for fixed life and the creation of a food chain, however, the reef becomes a full "habitat for fish and other aquatic organisms" that allows the many species appropriate to the locale to thrive.[7] The demand for reef materials depends on the state's specific coastal environment. All southern Atlantic states and Gulf Coast states have ocean bottoms off their coasts that are largely barren sand or mud and therefore have developed artificial reef programs in recent decades. To the contrary, northern Atlantic states—Massachusetts, for example—have ocean bottoms off their coasts that are already largely rock, so artificial reefs would add little to the habitat for sea life.

In addition to increasing and benefiting sea life, artificial reefs can be used for research on how habitat influences marine life and how to restore endangered or at-risk species. For example, we learned that the state of South Carolina would consider constructing a nursery and habitat for Atlantic grouper if sufficient ships were available at low cost. Atlantic grouper are apparently at risk because of over-fishing, and a large deepwater reef (at approximately 400 ft) is needed off the coast of South Carolina to rebuild their population. Such a reef could consume up to 100 large vessels.

Most artificial reefs are not deep water reefs, however. Most are placed in shallower water for convenient use by fishermen. The construction of artificial reefs for fishing purposes has long been managed by quasi-governmental marine fishery organizations. We interacted with two such groups: the Atlantic States Marine Fisheries Commission (ASMFC) and the Gulf States Marine Fisheries Commission (GSMFC). These two groups primarily represent the marine fishery interests for all states bordering the Atlantic and Gulf coasts. A representative from Florida serves on both commissions. While nominally focused on fisheries, these two organizations also consider the promotion of diving reefs to be within their responsibilities.

[7]Gulf States Marine Fisheries Commission, "Guidelines," p. 1.

Of all Atlantic and Gulf Coast states, Florida has been the most active in constructing fishing reefs. Florida is in many ways an ideal state for engaging in reef building. Its coastal waters are warm and shallow for many miles out toward sea. Large areas of its coastal ocean have barren sand and mud bottoms with a surface climate suitable for nearly year-round marine activities. Florida has over 300 existing reef sites employing over 400 metal vessels of all kinds and has permitted reefs to be built by state, county, and local governments as well as private organizations. Recently, private programs were suspended to secure better environmental control over reef building. Texas, South Carolina, and other coastal states also have active reef-building programs, but none is yet on the scale of Florida's.

At RAND's request, Mel Bell, of the state of South Carolina Department of Natural Resources and Tom Maher of the state of Florida's Division of Marine Fisheries conducted a brief survey of interest in artificial reefs along the Atlantic and Gulf coasts during the summer of 2000. Seven states responded; the results are presented in Table 5.1. As the table shows, there is a demand for more than 540 ships of all the sizes listed. These sizes correspond to the sizes of the 358 ships in the fleet awaiting disposal (see Appendix A). The existing reef system offers sites of adequate water depth for all ships. It even appears that ships as large as aircraft carriers would be welcome.

Because of the large demand for ship reefs off the Atlantic and Gulf coasts—a demand sufficient to consume the entire inactive ship inventory—we did not formally investigate the demand for ships off the West Coast or off the coasts of Hawaii or the Pacific Ocean territories.

Artificial Reefs for Sport Diving

The use of reefs for recreational diving is a modern development coinciding with the development of reliable scuba equipment shortly after World War II and the subsequent popularization of the sport of scuba diving. There are approximately 8.5 million certified scuba divers in the world, and the Professional Association of Diving Instructors (PADI) reports that their annual certifications, representing about 70 percent of all certifications, have been increasing by about 50,000 per year since the mid-1980s. The number of certifications translates into a continually increasing demand for interesting diving targets.[8] For example, ex-U.S. Coast Guard vessels *Bibb* and *Duane*, sunk off the Florida Keys, are important scuba diving targets. In July 2000, the San Diego Oceans Foundation (SDOF) sunk a Canadian destroyer escort, the ex-HMCS *Yukon*, off the coast near San Diego, California, as a recreational diving and fishing attrac-

[8]Gulf States Marine Fisheries Commission, "Guidelines," p. 55.

Table 5.1

Survey Results of Reefing Practices Among Atlantic and Gulf Coast States

	State							
	FL	MA	NY	NJ	SC	GA	TX	Total
Existing state program?	Y	Y	Y	Y	Y	Y	Y	
Existing county, municipal, or private reef program?	Y	N	N	N	N	N	N	
State oversight agency	F&W Con. Com.	Div. Mar. Fish.	Dep. Env. Con.	Div. of F&W	Dep. Nat. Res.	Dep. Nat. Res.	Parks & Wild-life	
State management plan?	Y	Draft	Y	Y	Y	Draft	Y	
State construction guidelines?	Y	Draft	Y	Y	Y	Y	Y	
Total number of existing permitted artificial reefs	>300	3	11	14	42	19	36	>422
Number <30 ft of water	18	1	2	-	12	0	0	33
Number 31–60 ft of water	17	2	4	4	19	14	8	68
Number 61–75 ft of water	30	0	4	5	4	3	1	47
Number 76–100 ft of water	32	0	1	3	5	0	4	45
Number >100 ft of water	42	0	0	2	2	2	23	71
Reasons for reefs								
Recreational fishing	Y	Y	Y	Y	Y	Y	Y	
Recreational diving	Y	N	Y	Y	Y	N	Y	
Habitat enrichment	Y	Y	N	Y	Y	Y	Y	
Commercial fishing	N	Y	Y	N	N	N	Y	
Fisheries stock enhancement	Y	N	N	Y	Y	Y	Y	
Other		Mitigation			Exp.			
Use metal vessels including ships, barges, and boats in past?	Y	N	Y	Y	Y	Y	Y	
Total no. of metal vessels in existing reefs	>400	0	65	100	230	33	18	>846
Ships <200 ft	112	0	0	7	166	1	0	286
Ships >200 ft	58	0	0	10	7	2	13	90
Ships of unknown length	15	0	0	0	0	0	0	15
Are metal vessels presently used?	Y	N	Y	Y	Y	Y	Y	
Would state use surplus ships in the future?	Y	Y	Y	Y	Y	Y	Y	
55–100 ft	Y	Y	Y	Y	Y	Y	Y	
101–200 ft	Y	Y	Y	Y	Y	Y	Y	
201–300 ft	Y	N	Y	Y	Y	Y	Y	
301–400 ft	Y	N	Y	Y	Y	Y	Y	
>400 ft	Y	N	Y	Y	Y	Y	Perhaps	
How many total?[a]	113	<12	15	>100	>100	>100	>100	>540
Limit on per-ship cost to state								
<$50K	Y	Y	Y	Y	Y	Y	Y	
$50–$100K	Y	N	N	Y	N	N	Y	
$100–$150K	N	N	N	N	N	N	Perhaps	
$150–$200K	N	N	N	N	N	N	N	
$200–$250K	N	N	N	N	N	N	N	
>$250K	N	N	N	N	N	N	N	
Minimum vertical profile of candidate ships	None	20 ft	None	5	None	None	20	
Maximum vertical profile of candidate ships	None	60 ft	35[b]	80	50[b]	70[b]	60	

[a]These states reported that they could use an unlimited number of ships. We entered >100.

[b]These states would create deeper sites if larger ships were available.

tion. By all reports, it was an instant success, swamping the diving and fishing businesses in the city during subsequent months. The Artificial Reef Society of British Columbia (ARSBC) has sunk five ships, including three sister ships of the *Yukon*, for the same purposes in different areas off the coast of British Columbia, Canada. The Lake Ontario Scuba Association is negotiating with the Canadian government to acquire the HMCS *Nipigon*, a frigate about the same size as the *Yukon*, which it wants to sink in Lake Ontario as a diving attraction. The government of Australia donated the ex-HMAS *Swan*, a destroyer escort, to the government of Western Australia for construction of a diving reef in 1997. A similar project involving the ex-HMAS *Hobart*, an ex-USS *Charles F. Adams* Class destroyer, is in progress off southern Australia. Diving vacation sites involving ships—whether they are wrecks or intentional for man-made reefs—are promoted in most if not all coastal nations.

There are no projections available on the demand for additional diving resources. However, literally hundreds of "dive center" businesses are situated along the U.S. coasts (and inland as well, for diving in lakes, rivers, and ponds) and diving proponents are actively seeking more ships. The sponsor of the *Yukon* project off California (discussed above) wants five additional ships at the site. A project involving the ex-USS *Speigel Grove* for reefing off Key Largo, Florida, has been in progress for many years. A new dive project managed by Artificial Reefs for the Keys (ARK) is working toward reefing the ex-USS *Gen Hoyte S. Vandenberg* off Key West. This project plans to include features and hardware for distance learning so that marine science can be taught throughout the United States.

During public hearings held in preparation for the Navy's ongoing Ship Disposal Project (SDP), the comments were overwhelmingly in favor of using inactive ships to build reefs. Of the 118 public respondents, 91 urged that the ships be used for reefs instead of being recycled. (Only two of the remaining 27 respondents expressed opposition to reefs, and the balance expressed no opinion on reefs.) Most of the diving individuals and groups that we contacted emphasized that divers are especially interested in warships with guns or gunlike structures as dive targets.[9]

Other Uses

There are many other potential uses for artificial reefs. We have already mentioned the Atlantic grouper nursery suggested by South Carolina. Also as already mentioned, ARK is proposing to use the *Vandenberg* reef for educational

[9]The *Yukon* was fitted with gun-barrel-like metal pipes to replace the original gun barrels before being sunk.

purposes. There are more. Some people have suggested using artificial reefs to grow specific forms of marine life for cancer research. Others suggest that ships be used as artificial reefs to prevent the loss of beaches, to relieve diving and fishing pressures on natural reefs, and to serve as underwater memorials to those who served aboard them.

Adequacy of Demand for Artificial Reefs

The demand for reefs off U.S. coasts was emphasized in a 1996 GSMFC resolution in which it was found that "the demand for ships and ship hulls for artificial reef applications far exceeds the supply." Noting the potential availability of unneeded Navy and MARAD ships, the GSMFC resolved that the "Commission strongly encourages the Department of the Navy to develop a mechanism to identify appropriate decommissioned Navy vessels and ships and to make those vessels and ships available . . . to State artificial reef programs for application as artificial reefs."[10]

The demand for fishery reefs alone is more than 540 vessels, and the demand for diving reefs and for other purposes will increase this number. We thus conclude that the demand for ships for use as artificial reefs—whether it be to provide habitat for marine life, to promote sport or commercial fishing, to provide sites for sport diving, or to do all these activities and more—is more than adequate to consume all 358 ships in the Navy and MARAD inactive fleets.

IMPEDIMENTS TO REEFING PROGRAMS

The impediments to building reefs with ships stem from environmental standards and the costs associated with preparing ships to those standards. Two of the reasons the ASMFC reported for why few MARAD ships have been deployed as reefs in accordance with the Liberty ship program were (1) lack of funds to prepare the ships and (2) uncertainties on how to handle pollutants such as PCBs and asbestos.[11] These issues remain to this day.

Additional impediments may ultimately arise from factions within the environmental community should a Navy-MARAD reefing program be initiated. We are aware of some concerns that artificial reefs are "killing zones" for fish and that they just attract fish from elsewhere rather than creating more fish. Arguments of this nature do not have credence within the coastal marine fishery or-

[10]Quotation from Chris Nelson, Chairman, in Gulf States Marine Fisheries Commission, "Resolution on the Use of Retired Navy Ships and Artificial Reef Materials," October 17, 1996.

[11]Atlantic States Marine Fisheries Commission, "The Role of Vessels," pp. 4 and 6.

ganizations we consulted, but they could certainly come up during a more visible Navy-MARAD reefing program.

State and Federal Standards

Given the continuing reefing activity along many state shores, we assume that each state has adequate rules for matters under its cognizance. There are, however, no uniform federal standards for areas under federal cognizance. The standards employed for any specific reefing project are usually generated by the organization responsible for the project in consultation with local and regional state and federal environmental and/or coastal zone regulators. For example, the *Yukon* project used Canadian standards amended by requirements from California state authorities. The standards invoked by South Carolina are expressed in two sentences requiring artificial reef materials to be "free of all oils, hydraulic fluids, fuels refrigerants and [anything else] that might be harmful to the marine environment and free of floating debris."[12] Implementation details of the "free of all" requirement are left to the specific project.

Significantly lacking are standards specific to the remediation of the solid nonmetallic materials containing PCBs that were first found in 1989 in Navy ships and subsequently found in all manner of ships. This area of environmental law is primarily a Federal responsibility. The GSMFC has issued advisory guidelines in their 1997 report and called on the EPA to expressly address the PCB question so that the unfettered use of ships might continue.[13] The Navy, in concert with the EPA, is sampling for the presence of environmental pollutants in the vicinity of sunken ships in both deep and shallow waters and is conducting laboratory studies of PCB behavior in seawater. The Navy is also conducting an environmental risk assessment regarding PCBs in the marine environment. This work may lead to uniform rules. Until it does, each reef-building project must confront the issue independently and employ standards acceptable to the local authorities at the current time.

U.S. Coast Guard Standards

The U.S. Coast Guard (USCG) has overcome these difficulties by developing, in concert with New Jersey and Maryland authorities, its own standards for the

[12]South Carolina Department of Natural Resources, "South Carolina Marine Artificial Reef Management Plan," Section 9.2.3, 1991.

[13]Gulf States Marine Fisheries Commission, "Guidelines." The GSFMC also advised its member states to continue using ships as reefs in accord with state standards pending EPA action. Note that the GSFMC apparently has no authority to issue binding environmental standards for use of ships as reefs.

conduct of its ships-to-reefs program. The ships in the program are small, the largest to date being a buoy tender with a displacement of less than 1,000 tons. Vessels are prepared at the USCG Baltimore, Maryland, shipyard and subsequently donated to New Jersey and Maryland for construction of reefs. The yard developed a cleaning protocol it believes conforms to reasonable requirements, but the USCG advised us that no other national agency has passed judgment on its actions. The USCG plans to clean and provide up to 70 vessels for reefs over the next few years, which is essentially all of its unneeded ships that cannot be sold or donated for continued use elsewhere.[14] The standards being employed by the USCG are summarized in the following sections.

PCB Removal. The USCG yard removes all material contaminated with PCBs above 50 ppm. This includes felt gasket and faying material, electric power cables, paints, rubber gaskets, and other materials. The yard has developed several eyeball tests for materials based on the results of about 2,000 analyses of samples performed over the past 2 years. The eyeball tests include

1. Remove and dispose of (as PCB waste) electric power and signal cables dating from 1980 and earlier; retain all cables dating from 1984; and test all cable dating from 1980 to 1984 if the amount warrants, otherwise remove.
2. Remove and dispose of all potential PCB-felt products, including joinerwork bulkheads assembled with felt, faying materials between engine mounts and the ship's hull, faying material between deckhouse and hull, and others.
3. Remove and dispose of plastic foam hull insulation and fiberglass insulation located close to felt joinerwork materials. (Fiberglass insulation is thought to be contaminated by migration of PCBs in the PCB-felt in contact with joinerwork panels.)
4. Leave plastic gaskets in place if there is reason to believe they were new in 1985 or later. Thus, for example, door gaskets, which are replaced annually on vessels in service, are left in place—provided the ship was operational after 1984 (and all have been so far).

Water blasting is the primary tool for removal of PCB surface contamination, which occurs largely in PCB-laden felt. The acceptance criterion is the same as in federal regulations regarding spills of liquid PCBs (49 CFR 761): less than 10 micrograms per 100 cm^2. The yard finds that water blasting is effective for removal of felt-contaminated paints and surface residues and permits the solid residues to be easily filtered out. The water used in blasting is disposed of as ordinary industrial effluent.

[14]Personal interview with Cohen and Petagno, USCG Shipyard, Baltimore, MD, by Hess and Rushworth, RAND and MSCL, Inc., January 13, 2000.

The yard has not found PCBs in paints, oils, hydraulic fluids, and greases used in USCG vessels, although with the exception of paints, most of these materials are removed as oils.

All electronic systems—whether or not they contain PCBs—are removed, primarily for continued use. The USCG uses the same radars and communications and navigation equipment in many classes of vessels, so equipment removed from one can be used in others.

Asbestos Removal. The yard removes all asbestos-containing products. The usual approach is to remove the entire part or component that has asbestos on or in it and dispose of that part or component in a landfill as asbestos waste. The yard has found this approach to be less expensive than attempting to remove asbestos and leave the part/component behind. All vessels prepared for reefing to date have been diesel powered, which means they will have little propulsion system thermal insulation compared to steam-powered vessels.

Many USCG vessels use "Marinite" joinerwork bulkheads throughout. Older Marinite that contained asbestos is removed; newer, asbestos-free Marinite is left in place. Note that Marinite is common in MARAD ships but that the Navy has seldom used it (because it is brittle and will not withstand shock).

Removal of Oil, Weapons, and Debris. Fuels and lubricants are removed and the tanks flushed. Engines are removed either for reuse or to assure that all oil is removed before reefing. The yard has found that it is less expensive to remove and dispose of the engines than to try to clean the oil from them. The USCG is very sensitive to the possibility of an oil slick following a reefing and thus is very careful to ensure that all oil is removed from every tank, component, part, and all nooks and crannies.

The yard removes all weapons from ships. It also removes all loose debris and broom-sweeps all decks and bilges clean.

The resulting hulks are virtually stripped of everything. Two photographs of the buoy tender, USCG *Red Beach,* which was being converted for reefing early in 2000, are shown in Figures 5.1 and 5.2. The engine room shown had not yet had all of its debris removed.

Note that the USCG standards do not explicitly include actions to make ships safe for divers. However, ships are essentially made safe for divers by having their machinery, cables, and nearly everything else except bulkheads and overheads removed before they are sunk.

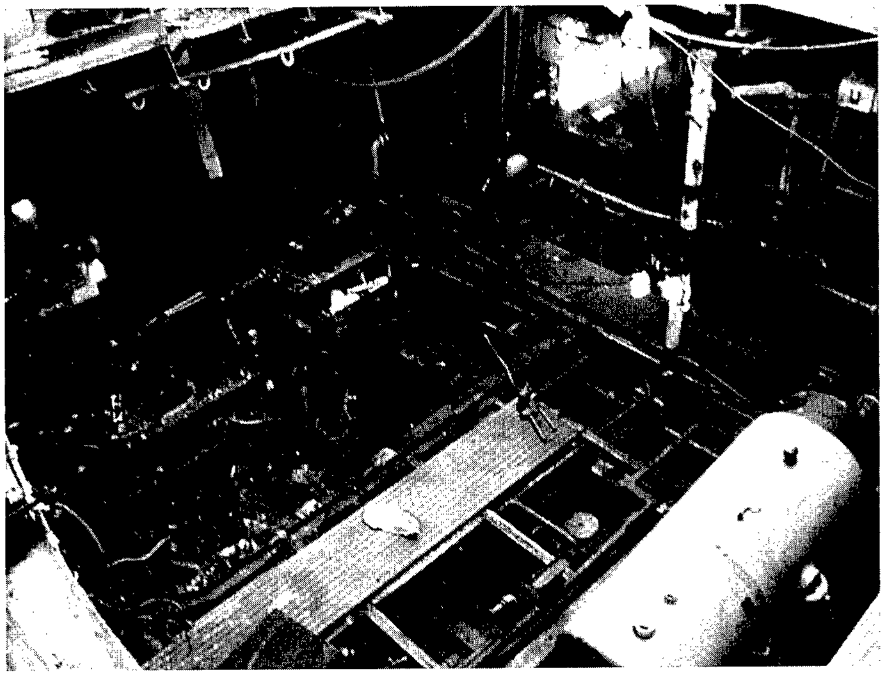

Figure 5.1—*Red Beach* Engine Room Stripped of Machinery and Ready for Final Cleaning

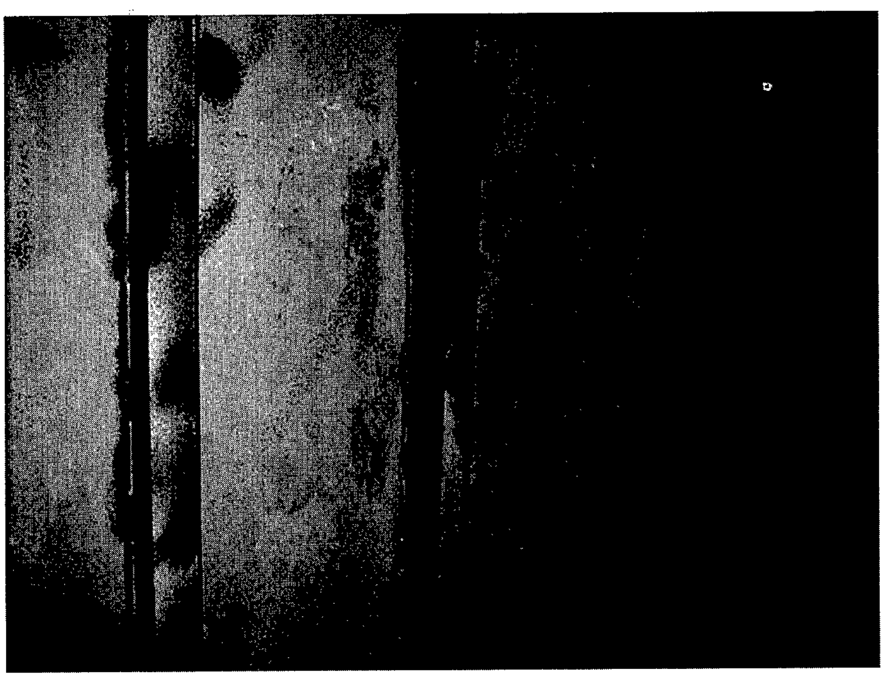

Figure 5.2—*Red Beach* Bulkhead Stripped of Joinerwork and Water Blasted

Canadian Standards

Canadian organizations have prepared and sunk several ships for reefs during the past decade. To support Canadian programs, Environment Canada, the equivalent of the U.S. EPA, has developed rules for preparation of ships.[15] The rules and their draft predecessors were used to prepare the Canadian ships HMCS *Columbia*, *Saskatchewan*, and *Mackenzie*, naval frigates all roughly 2,300 tons in displacement. The Environment Canada rules were also used for the *Yukon* project, although we were informed that the Southern California Water Resources Board required additional cleaning of oil residues from the ship's machinery. The Canadian rules are comparable to the USCG practice with the following exceptions:

1. PCB-containing components must be removed, but PCB-bearing paint, plastics, and rubber may remain in place. (California authorities allowed such materials to remain in place in the *Yukon*.)
2. Intact, undisturbed asbestos insulation need not be removed, but any loose or unsealed asbestos must be sealed or removed to protect workers.
3. Machinery need not be removed if it is cleaned so as to be visually free of oil.

Navy SINKEX Standards

The Navy occasionally uses unneeded ships as targets for military exercises termed *sinking exercises*, or *SINKEX*. The Navy holds general permit for this activity from the EPA. Among the requirements is that ships be sunk in 6,000 feet or more of water and that they be cleaned to Navy SINKEX standards, which require removal of oils and greases, PCB-containing electrical and electronic equipment, and other "readily removable" PCB-containing equipment. As is appropriate for deep-sea sinking, the standards are less restrictive than the Environment Canada standards for shallow-water reef building.

THE COST OF A DOMESTIC REEFING PROGRAM

Funding for reef building has always been tight. Among the six states discussed in the 1994 ASMFC report, the average annual expenditure for preparing ships was only $25,000, of which 8 percent was state funding, 13 percent federal funding (from the Federal Aid in Sportfish Restoration Program), and the bal-

[15]Environment Canada, "Cleanup Guideline for Ocean Disposal of Vessels" and "Cleanup Standard for Ocean Disposal of Vessels," Pacific and Yukon Region, February 1998.

ance came from private or unknown sources.[16] Six states reported building reefs with ships without spending any state money. The information presented earlier in Table 5.2 suggests that at least some states would be willing to spend as much as $100,000 to prepare a ship for reefing. This amount is significantly more than the $25,000, but it is also significantly less than the full cost of such a program for anything other than the smallest vessels, as is discussed below. Clearly, cost is the weak point in many reefing programs.

Notionally at least, a reefing program should have cost elements comparable to those of the domestic recycling program discussed in Chapter Three—i.e., the cost to prepare the ship for use as a reef, the cost for tow preparation and towing, the cost of storage of ships awaiting reefing, and revenue from the sale of materials removed from the ship for reefing. During our search for information on reefing matters, we could find no consistent information on revenues from the sale of materials removed from ships to be reefed. Information from commercial and nonprofit organizations shows such revenues as an important source of funds for supplementing these organizations' usually meager budgets, but the USCG reported no revenues for their program. As a consequence, we have omitted such revenues from our overall program cost estimate.

Estimating the Cost of Preparing Ships for Reefing

The USCG provided us with return and budgeted costs for preparing 16 types of vessels in accordance with its standards. These costs are for all work at the shipyard, including local towing and docking, preparation work, and all incidental overhead items. They do not include the cost to tow the vessel to the sinking site. The vessels have all been small, ranging from 44-foot motor lifeboats displacing 13 tons to 180-foot buoy tenders displacing 935 tons. The incentive for this program is strictly cost: the USCG says it is much less expensive to clean a ship for reefing than to recycle it.

Both the SDOF, which sponsored the *Yukon* project, and the ARSBC, which sponsored the sinking of the *Yukon*'s three sister ships, also provided us with cost information for preparation of their ships.[17] The costs reported by these organizations are for storage at the preparation site, towing, preparation work, insurance, and other elements of doing business. In addition to being environmentally cleaned, these ships were prepared to be "safe for divers" according to standards set by the local diving groups involved in the project. Making

[16] Atlantic States Marine Fisheries Commission, "The Role of Vessels."

[17] San Diego Oceans Foundation letter dated October 11, 2000, to Denis Rushworth, MSCL, Inc.; and Artificial Reef Society of British Columbia letter of September 27, 2000, to Denis Rushworth, MSCL, Inc.

these ships "safe for divers" meant such things as opening large holes in the hull's side and top to provide divers free access to the ship's interior, sealing off via welding or filling with concrete all areas that could not be made safe, and removing cables from the deck overheads to prevent them from falling on divers when the cable trays ultimately fail. To achieve a uniform cost comparison across all options, we made some adjustments to the cost data provided. The ARSBC costs included 75 man-months of donated labor per ship. We converted these donations to costs at the rate of $45 per hour. The SDOF costs included promotional costs, which while essential for the program (because it was not government supported), were not truly costs for ship preparation. We struck these. We also struck towing costs because they are accounted for separately in our final cost estimate figures, and we struck all revenues from sales.

The National Steel and Shipbuilding Company (NASSCO) provided us with return costs from prior ship preparation programs and an estimate for the environmental preparation of CG16, CG26, and DDG 2 Class ships, not including diver-safe preparations. These ships are all roughly 5,000 tons light ship weight. The NASSCO estimate focuses on removing oils and lubricants from the ships, cleaning bilges, and removing oil-containing piping. It does not include costs for removing electric and electronic PCB-bearing equipment, electric cables, and asbestos or for the other items subject to the Canadian standards, nor does it include costs for towing the ships to the yard for preparation work or to the sinking site. Finally, the SDOF provided us with a rough order-of-magnitude cost estimate (with a high- and a low-cost boundary) for non-diver-safe preparation of ships according to the Canadian standards that the Foundation had received from a consortium of San Diego shipyard representatives.[18]

Table 5.2 presents the cost information from the different organizations, and Figure 5.3 presents the same information as a graph. The figure reflects all of the data and estimates but does not discriminate between diver-safe projects, such as *Yukon*, and non-diver-safe projects because there was not enough fine structure in the data to permit this. As can be seen, the data fall on a tightly clustered line. Note that the low data point, at about 5,000 tons, is the NASSCO estimate, which includes the cost for environmental preparation and focused on oil removal. The other data represent more-comprehensive environmental preparations and in many cases include diver-safe preparation. Using the equation in Figure 5.3, one sees that preparation of a 5,000-ton ship would cost about $1.0 million (substantially higher than NASSCO's estimate of $0.6 million) whereas preparation of a 15,000-ton ship would cost about $1.7 million.

[18]Estimate provided by Dick Long of SDOF in interview by Hynes (RAND) and Rushworth (MSCL, Inc.), Summer 2000.

Table 5.2

Costs to Prepare Ships for Reefing

Vessel	Cleanup Standards	LSW Tons	Preparation Cost Minus Ship Purchase (US$)	US$/ LSW Ton	Reefing Date	Source
USCG 55' ANB	USCG	22	82,500	3,750	NR	USCG
USCG 44' MLB	USCG	13	46,000	3,538	NR	USCG
USCG 82' WPB	USCG	55	120,000	2,182	NR	USCG
USCG 65' WLI	USCG	54	97,500	1,806	NR	USCG
USCG 65' WYTL	USCG	57	97,500	1,711	NR	USCG
USCG 100' WLI	USCG	141	150,000	1,064	NR	USCG
USCG 100' WLIC	USCG	141	150,000	1,064	NR	USCG
USCG 75' WLR	USCG	111	112,500	1,014	NR	USCG
USCG 115' WLR	USCG	230	230,000	10,000	NR	USCG
USCG 75' ANVIL	USCG	114	112,500	987	NR	USCG
USCG 75' WLIC	USCG	114	112,500	987	NR	USCG
USCG 65' WLR	USCG	103	97,500	947	NR	USCG
USCG 157' WLM	USCG	471	340,000	722	NR	USCG
USCG 133' WLM	USCG	435	266,000	611	NR	USCG
USCG 180' WLB	USCG	935	500,000	535	NR	USCG
USCG 180' WIX	USCG	935	500,000	535	NR	USCG
HMCS *Columbia*	Canadian	2,390	241,662	338	1996	ARSBC
HMCS *Saskatchewan*	Canadian	2,380	223,496	331	1997	ARSBC
HMCS *Mackenzie*	Canadian	2,380	148,665	299	1995	ARSBC
HMCS *Yukon* environment and diver safe	Canadian	2,380	799,136	336	2000	SDOF
2300-ton frigate, U.S. yard estimate, environment and diver safe, low	Canadian	2,300	500,000	217	N/A	San Diego Consortium
2300-ton frigate, U.S. yard estimate, environment and diver safe, high boundary	Canadian	2,300	700,000	304	N/A	San Diego Consortium
CG16, CG26, DDG2 average ship, environment but not diver safe	NASSCO	5,050	579,051	115	N/A	NASSCO ROM
Project *Vandenberg* low, environment safe, diver safe	Local	14,300	1,700,000	119	NR	Jeff Dey, ARK
Project *Vandenberg* high, environment and diver safe	Local	14,300	2,000,000	140	NR	Jeff Dey, ARK

NOTES:

(1) In the case of the HMCS *Columbia, Saskatchewan,* and *Mackenzie,* the costs were provided in Canadian dollars. We used a 0.70 conversion factor to convert to the U.S. dollar amount shown.

(2) NR, in Reefing Date column, indicates no record.

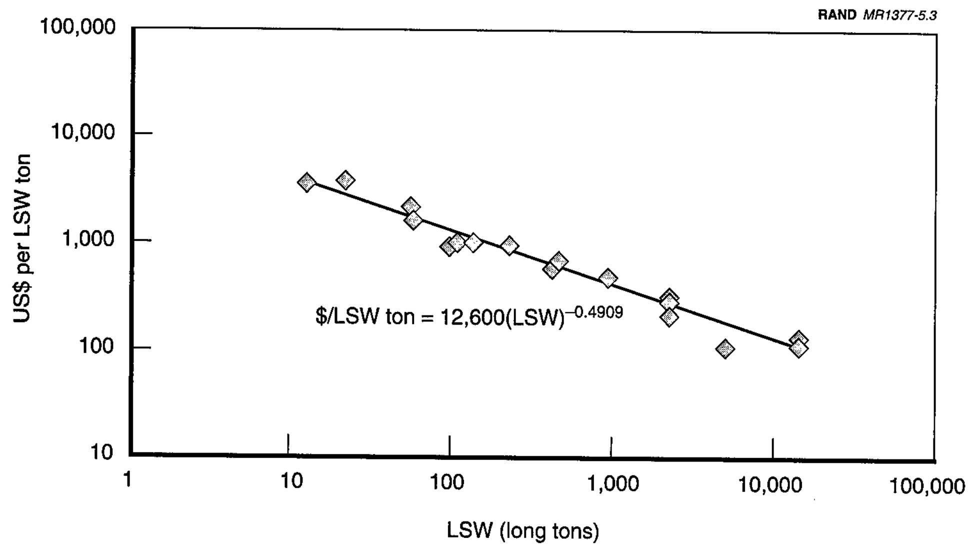

Figure 5.3—Cost per LSW Ton of Preparing Ships for Reefing

Estimating the Error in the Reef Preparation Cost

Our statistical regression analysis of the data shown in Figure 5.3 indicated excellent correlation between cost per ton and ship tonnage. The standard error from the analysis is ±16 percent. We also allowed for an escalation in labor costs similar to that for domestic recycling. This amounts to a ±30 percent error band. We applied these errors to the costs in calculating the best-case and worst-case estimates.

Estimating the Cost of a Reefing Program

Using the equation in Figure 5.3 to calculate the cost to prepare all 358 ships in the inactive fleet (see Appendix A, Table A.2) for reefing, we arrive at a total cost of $393 million in FY00 undiscounted constant dollars. This is, however, just the cost to prepare the ships. We must also consider tow preparation and towing, storage, the learning curve, and the various other factors we used to estimate the cost of a domestic recycling program in Chapter Three. To compute the total program cost, we used a cost model similar to the one we used for domestic recycling. Table 5.3 shows the baseline inputs to this model.

Table 5.3

Baseline Inputs to Reef Program Cost Model

Towing cost ($/mile of tow distance)	224
Outfitting cost ($/ship/tow)	100,000
Average recycle tow distance (miles/ship)	525
Average dismantling cost ($/ton)	142
Navy annual O&M per ship designated for scrap	57,000
MARAD annual O&M per ship designated for scrap	20,000
Weighted average annual storage O&M per ship designated for scrap	33,431
Annual storage O&M aging factor (%/year)	0.5
Discount factor (decimal) for discounted cost calculation	0.041
Preparation improvement curve slope (decimal) (log-linear unit)	0.95
Number of preparation sites	4

These inputs yield a baseline cost estimate of $500 million in undiscounted FY00 dollars, or $370 million discounted. For the best-case cost estimate, we used a 90 percent learning curve, and the lower end of the error envelope for ship complexity (-16 percent) and labor costs (-30 percent). The result is $320 million in undiscounted FY00 dollars, or $240 million discounted. For the worst-case cost estimate, we used a flat learning curve and the upper end of the error envelope for both ship complexity and labor costs. The result for this cost is $760 million in undiscounted FY00 dollars, or $560 million discounted.

In terms of annual average cost spread over a 20-year program, the budget would start at about $35 million per year and then fall to about $20 million per year in the last years as the learning curve reached maximum effect and the storage cost for the remaining ships declined. Figure 5.4 shows the annual budget for a 20-year reefing program.

As discussed in Chapter Three, the separate Navy and MARAD annual budgets are affected by how many ships each agency holds title to. Figure 5.5 shows the separate Navy and MARAD annual budgets for the reefing program, based on the baseline cost estimate, if title to the 358-ship inventory remains as it is now. Figure 5.6 shows the separate annual budgets (baseline cost estimates again) that would result if the Navy were to transfer 47 ship titles to MARAD. Note that these estimates include ship storage costs, which amount to about one-third of the total cost of the reefing program. We did not examine the current Navy and MARAD budgets, but we presume they include ship storage. Budget additions beyond the current levels thus would have to be only about two-thirds of the estimated total costs given above.

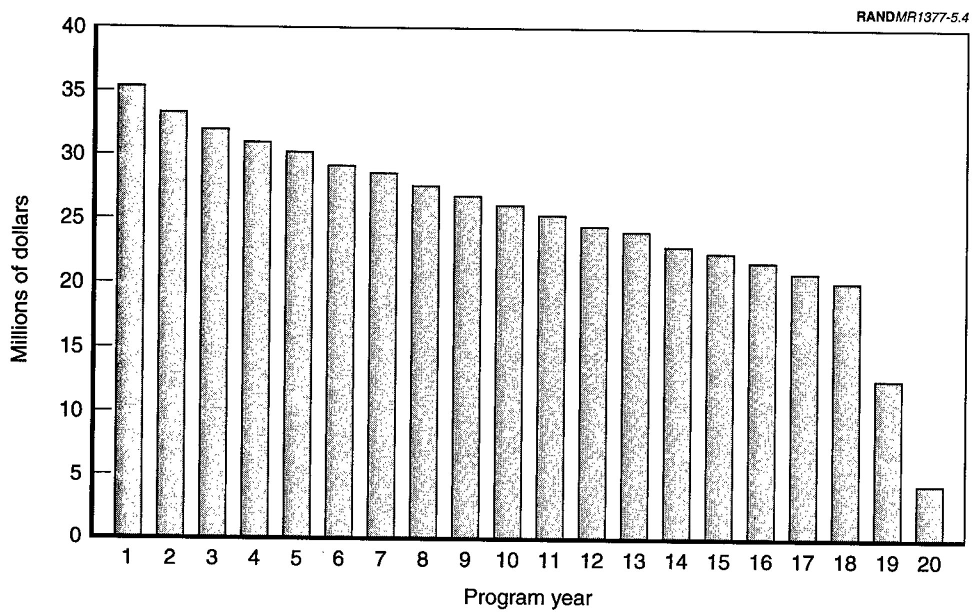

Figure 5.4—Annual Budget for Reefing

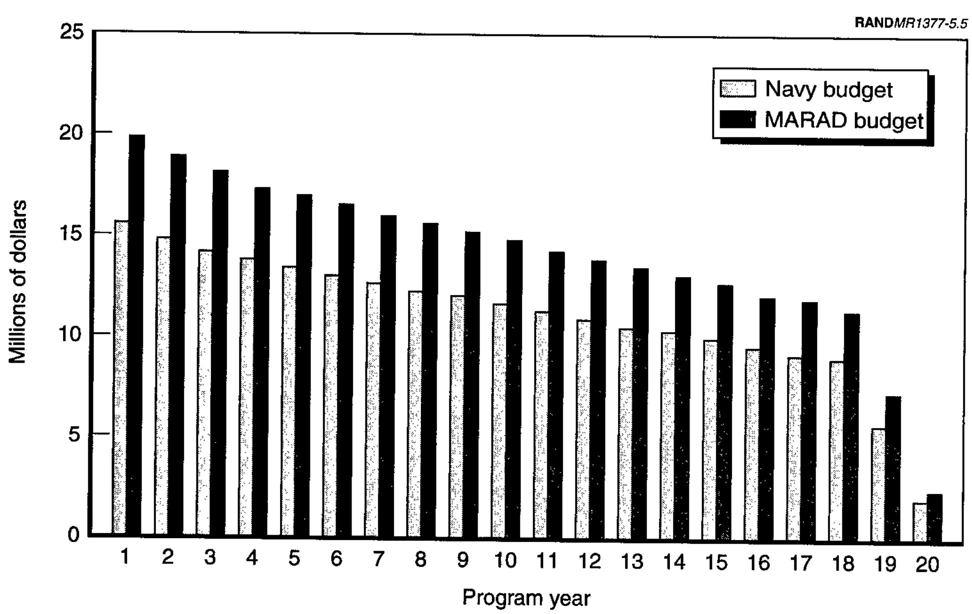

Figure 5.5—Annual Navy and MARAD Budgets for Reefing, Without Additional Title Transfers

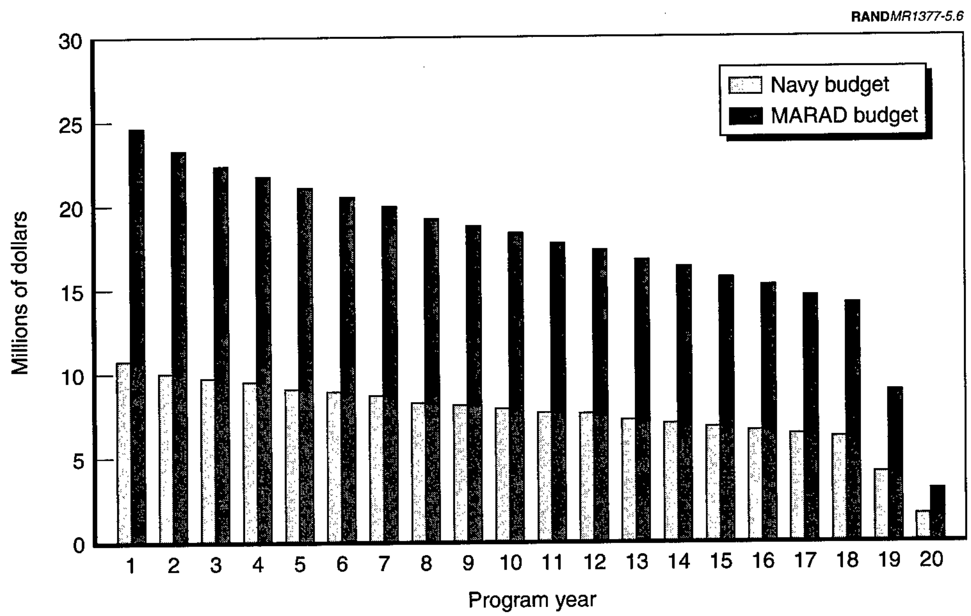

Figure 5.6—Annual Navy and MARAD Budgets for Reefing, With Additional Title Transfers

One issue we did not analyze is whether each agency should run its own reefing program with its own ships or whether one of the agencies should manage all the ships. It seems logical that the latter arrangement would be chosen for the sake of efficiency, in which case total program cost will remain the same but the entire budget will fall to the one agency. The government thus could achieve a small savings over our estimates by storing reef-program ships at MARAD rather than Navy facilities.

THE ECONOMIC BENEFITS OF ARTIFICIAL REEFS

Artificial reefs already provide returns to the government, and new reefs created with unneeded Navy and MARAD ships will provide more. Artificial reefs promote recreational and commercial fishing and recreational diving, activities that are of economic benefit to local and more-distant economies. Studies of how beneficial these activities are have been done, but they have not been well controlled and therefore provide only incomplete estimates. The state of Florida is now performing what is intended to be a definitive study, but its results are not yet available.

Table 5.4 summarizes the available data on the benefits of artificial reefs. As can be seen, some data reflect estimates of revenue from sport diving only, some from recreational fishing from private boats only, and some from all fish-

Table 5.4

Economic Benefits of Artificial Reefs

Geographical Area	Site	Months/ Year in Use	Local Annual Gross Receipts (US$M) Rec. Diving	Rec. Fishing	No. of Sites	No. of Ships Planned	Actual	Millions of US$/ site/ yr	Millions of US$/ ship/ yr	Sources	Comments
San Diego, CA	Wreck Alley	2	11.4		1	6	1	1.4	0.9	SDOF, 3/97	Diving estimate projected for a 6-ship site
Scapa Flow, UK	Scapa Flow	5	2.5		1	10	0	0	0.6	SDOF, 3/97	Est. SDOF of Scapa Flow diving revenue in US equiv.
Dunsborough, WAU, AU	HMAS *Swan*	0	1.48		1	1	1	0.8	0.8	Geoff Paynter, Geography Bay, ARSBC	
Sidney BC, Canada	G.B. Church & HMCS *Mackenzie*	9	2		1	2	2	0.7	0.3	ARSBC financial report, 1996	
Sechelt BC, Canada	HMCS *Chaudiere*	9	1		1	1	1	0.3	0.3	ARSBC	
Campbell River, BC, Canada	HMCS *Columbia*	9	1		1	1	1	0.3	0.3	ARSBC, 1996	
Nanaimo BC, Canada	HMCS *Saskatchewan*	9	1		1	1	1	0.3	0.3	ARSBC, 1998	
Various SC, USA	South Carolina	9		18	2	173	73	0.58	0.1	R. J. Rhodes et al., 3/94	
Florida	Dade County, FL[a]	2		0.16	1			0.16		J.W. Milon, 12/87	Private recreational fish, low, per site
Florida	Dade County, FL	2		0.94	1			0.94		J.W. Milon, 12/87	Private recreational fish, high, per site
Various SC, USA	South Carolina	9		18	8			0.87		R. J. Rhodes et al., 3/94	Recreational fish, all SC sites
Port San Luis, CA	San Luis Obispo County	2		1.2	1			0.2		D.B. Rockland, 1990	Party boat fishing only
Florida	5 Counties, NW Florida[a]	2		414	8	9		6	0	F. W. Bell et al., 1998	Recreational fish NW Florida
						Avg.	2.7	1.9			

[a]Number of sites and ships for this location provided by Tom Maher, Florida Fish and Wildlife Commission, in personal interview.

ing but no diving. We chose to list and average all data so that we could develop a rough estimate of how much local business revenue could be realized per ship and per site. We also chose to express the results as if the sites/ships were located in coastal areas where fishing or diving activities would be year round—i.e., off the coasts of the southeastern and Gulf Coast states, California, and Hawaii. As shown in the table, we estimate the average annual gross revenue to be $2.7 million per reef site and $1.9 million per ship. There are over 400 existing artificial reef sites (see Table 5.2), some of which are ready to accept additional ships. If 100 such sites were to consume all 358 available Navy and MARAD ships (just under 4 ships per site), these sites would, we estimate, yield $270 million per year in gross business revenue. If the estimate were based on the number of ships, then the gross business revenue would exceed $680 million per year.

Federal receipts have for many decades averaged about 19 percent of gross national product (GNP) almost regardless of tax rates or tax policy.[19] Allowing an additional 6 percent for state and local income, sales, and other taxes, a total of about 25 percent of gross business revenue ends up in local, state, or federal coffers. Thus, from a fully developed reef program with all ships in place, federal, state, and local governments together can expect from $68 million to $170 million per year in receipts. Total government receipts will be sufficient to compensate for the entire program cost by midway through the twelfth year using the per-ship revenue estimates.[20]

CONCLUSIONS

The use of inactive Navy and MARAD ships for artificial reefs is a viable option. The overall program is estimated to cost $495 million, with a range of $320 million to $760 million. These costs represent a program to prepare ships for reefing in accordance with modern environmental requirements—criteria that seem high compared with the standards of state and local reef-building interests. Therefore, the demand for large U.S. government ships has been low. But if a ship preparation program funded by the Navy and MARAD could resolve the cost issue, there is sufficient reef-building demand to consume all 358 ships in the inventory. The average annual budget for a reef-building program will run from $10 million to $15 million in the Navy and from $20 million to $25 million in MARAD, depending on the number of Navy-to-MARAD ship title transfers that take place and how the program is administered. Additionally,

[19]Joint Committee on Taxation, U.S. Congress, 1986.

[20]The government will also derive tax revenues from the sale of scrap metals and equipment for a domestic recycling program, as discussed in Chapter Three.

federal, state, and local government receipts from the fishing and diving businesses that will use the reefs will be sufficient to compensate for the entire average cost of the program after about 12 years and, thereafter, will yield a net "profit" to the government.

To begin a Navy and MARAD reef-building program, the U.S. government will need to develop a uniform set of rules for ship preparation that covers all federal environmental responsibilities and meshes properly with state environmental responsibilities. In addition the Navy and MARAD will need to work out the details of how to administer such a program so that ships are fairly distributed among the many parties likely to request them.

ANALYZING THE SHIP DISPOSAL OPTIONS

Chapters Two through Five examined the option of long-term storage and the three ship-disposal options: domestic recycling, overseas recycling, and reefing. This chapter reports on our comparative analysis of these four options and points the way toward the most cost-effective and environmentally sound course of action.

REMOVAL OF THE OVERSEAS RECYCLING OPTION

Congress recently considered legislation that would have directed the Navy and MARAD to renew foreign recycling. The initiative failed but may come up again in the future. We concluded that despite the favorable cost of the overseas recycling option for ship disposal, the number and breadth of the impediments it involves make its reliable implementation unlikely without congressional action. And even then, overseas recycling might face insurmountable problems under international law should the Basel Convention decide to regulate the ship recycling practice. It is our conclusion that neither the Navy nor MARAD should attempt to restart the overseas recycling of U.S. government ships until and unless Congress resolves the impediments and directs such a program.

COMPARATIVE ANALYSIS OF REMAINING THREE OPTIONS

Table 6.1 summarizes the cost estimates for the remaining three options: long-term storage, domestic recycling, and reefing. The long-term storage option assumes that the fleet will be maintained for 100 years. The recycling and reefing options anticipate 20-year programs to dispose of the entire inventory of 358 inactive ships.

Long-Term Storage

Long-term—i.e., 100 years—of storage will cost about $4.9 billion in undiscounted FY00 dollars, or about $1.2 billion discounted. The undiscounted cost

Table 6.1

Summary of Cost Estimates for Domestic Disposal Options

Option	Undis-counted Baseline	Undis-counted Range	Discounted Baseline	Average Annual Budget: Navy		Average Annual Budget: MARAD	
Long-term storage	$4.9B	$3.8–$7.7B	$1.2B	$20M–$25M		$25M–$34M	
				Without Title Transfers	With Title Transfers	Without Title Transfers	With Title Transfers
Domestic recycling	$1.9B	$0.7–$3.6B	$1.4B	$42M	$28M	$52M	$66M
Reefing	$0.5B	$0.3–$0.8B	$0.4B	$11M	$8M	$14M	$17M

could be reduced to about $4.3 billion if all ships were stored at MARAD facilities. The average annual budget impact should be $50 million. As Chapter Two indicates, the accuracy of the cost estimates depends on the performance of three variables: the aging factor, costs associated with dry docking, and the interval between dry dock inspections. Figure 6.1 displays the sensitivities associated with these variables. It shows that each variable is somewhat sensitive, with the aging factor being the most sensitive. Should the aging factor increase

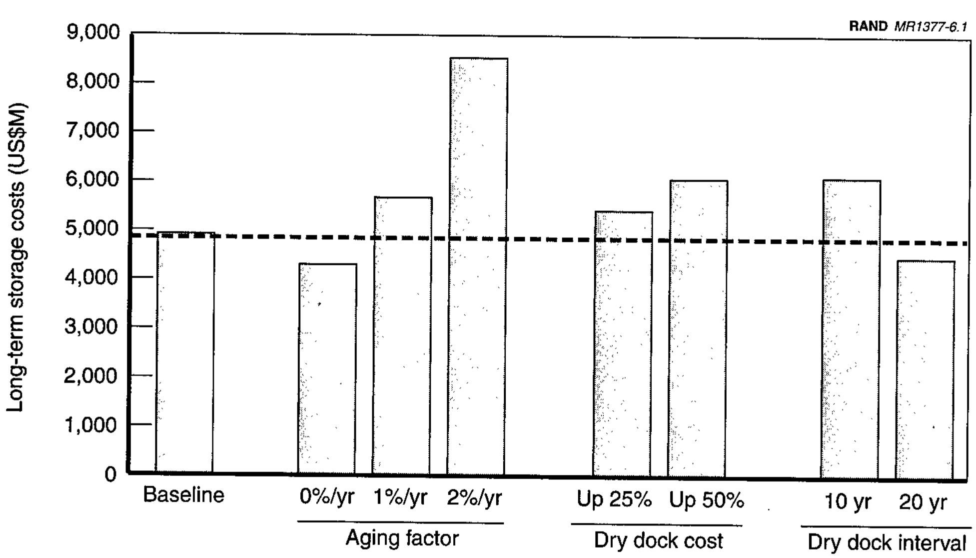

Figure 6.1—Sensitivities Within Long-Term Storage Costs

from the 0.5 percent per year used in the baseline case to 2 percent per year, the total costs could double. Dry dock costs and intervals may be somewhat less sensitive. Nevertheless, as Chapter Two notes, if a series of spills or increased corrosion problems were to cause fleetwide dry-dock intervals to decrease from 15 years to some shorter period of time, costs could rise.

Domestic Recycling

We estimate the total cost of the domestic recycling option to be about $1.9 billion in constant FY00 undiscounted dollars, or $1.4 billion in discounted dollars. While the number of ship titles each agency holds does not affect this total, it does affect the separate agency budgets. As title now stands, the Navy annual budget for this option would average $42 million, and MARAD's would average $52 million. If the Navy transfers to MARAD title to the 47 amphibious warfare and auxiliary ships in the 358 ship inventory, the average Navy inactive fleet budget will fall to about $28 million while MARAD's rises to about $66 million (see Chapter Three, Figures 3.4 and 3.5).. The accuracy of these cost estimates depends on three variables: cost factors associated with dismantling the ships, cost savings from learning to be more efficient in the actual recycling process, and the potential to produce cost-offsetting revenues.

In addition, the accuracy of these estimates is sensitive to the value of four variables in the cost model. To account for complexity differences between the different ship classes, we adopted the ship complexity trend we used for the reefing option. This trend has a ±16 percent error band. The labor costs we used are from PSNS and the SDP contractors; the average value of these data has a ±30 percent error band. The learning curve for the heavy industry market is generally 95 percent; however, the range could be anywhere from 90 to 100 percent. Finally, scrap prices for ship recyclables vary greatly. To assess this sensitivity, we allowed for a ±50 percent variation.

Dismantling costs include a great deal of manual labor, and the manual labor cost factor is among the most sensitive elements in the domestic recycling cost estimate. The Navy SDP contractors report that about half the cost of recycling a ship is in the dismantling phase, which is highly labor intensive. We believe better estimates will be possible as data on different classes of ships become available from the SDP.

Climbing the learning curve and discovering efficiencies could produce cost savings. A domestic recycling program should focus on providing a reliable, steady supply of ships to each contractor, perhaps sorted by ship type, to maximize efficiency gains. Each contractor may have different efficiency drivers, so the U.S. government will need to pay close attention if learning beyond the 95 percent learning curve used in our analysis is to be achieved.

Should PSNS's experience of having learning efficiencies overcome by a growth in environmental costs be seen by other recyclers, then there may be no cost savings from learning. We coupled the ±46 percent starting point error with both 95 percent and 0 learning to produce, respectively, a minimum and a maximum cost estimate for the domestic recycling option.

Scrap prices, as noted above (and as detailed in Appendix D and discussed in Chapter Three), can be quite volatile. However, fluctuations in scrap steel prices have relatively little impact on the cost estimate for this option.

Figure 6.2 illustrates all of the sensitivities for the domestic recycling costs. The range of the total program cost for this option is very large. As a result, we believe that should this option be selected, the U.S. government will need to place long-term contracts with experienced ship recycling firms that are carefully monitored for progress and cost containment.

Reefing

Reefing is the least expensive domestic disposal option. Our baseline estimate for a 20-year reefing program is based on a 95 percent learning curve and a best fit to the available data for ship complexity and labor costs. For these conditions, our cost estimate is $500 million in constant FY00 undiscounted dollars, or $370 million discounted. Our best-case estimate is based on a 90 percent learning curve and the lower end of both the complexity error band (-16 per-

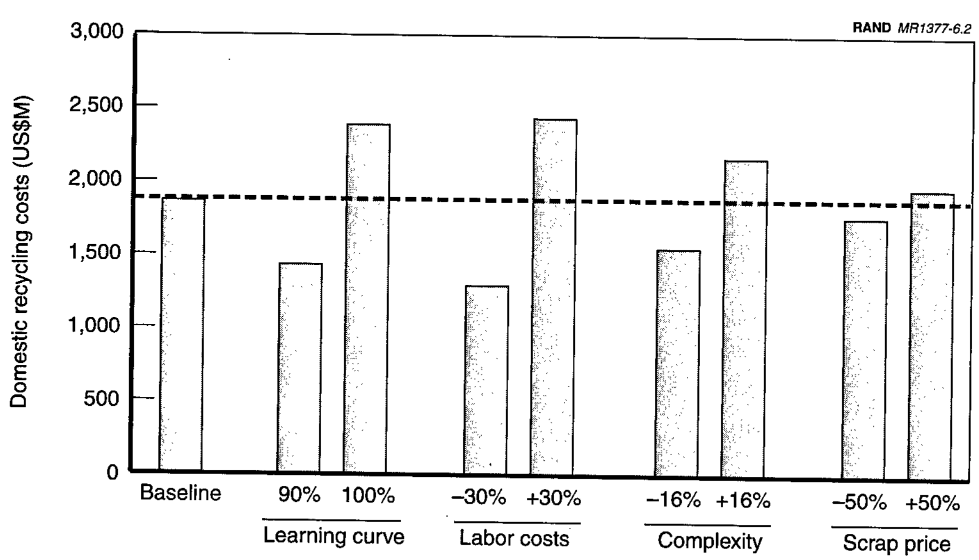

Figure 6.2—Sensitivities Within Domestic Recycling Costs

cent) and the labor cost error band (-30 percent). For these conditions, we arrive at $320 million in constant FY00 undiscounted dollars, or $240 million discounted. Our worst-case estimate is based on a flat learning curve and the upper end of both the complexity and the labor cost error envelopes. It is $760 million in constant FY00 undiscounted dollars, or $560 million discounted.

As with the domestic recycling option, each agency's annual inactive fleet budget will depend on the number of ship titles the agency holds. As the titles now stand, the Navy's annual budget for this option would average $11 million, and MARAD's would average $14 million. With title transfer to MARAD of the Navy's 47 auxiliary and amphibious warfare ships, the Navy's annual budget would average $8 million, MARAD's about $17 million. Our cost estimates include ship storage equaling about one-third of the total cost. If the ship storage expense is already in the existing agency budgets (we have not seen them), the actual budget increase required to implement the reefing option could be one-third less than the figures given.

As was also the case for domestic recycling, the learning curve has an important effect on reefing program cost. Figure 6.3 illustrates the range of costs based on our baseline, best-case, and worst-case costs and the sensitivity of the baseline to learning curves of 90 and 100 percent. For comparison, the figure also includes the cost to prepare all 358 ships for sinking exercises (SINKEX) at the average cost (reported to us by the Navy) of $75 per ton.

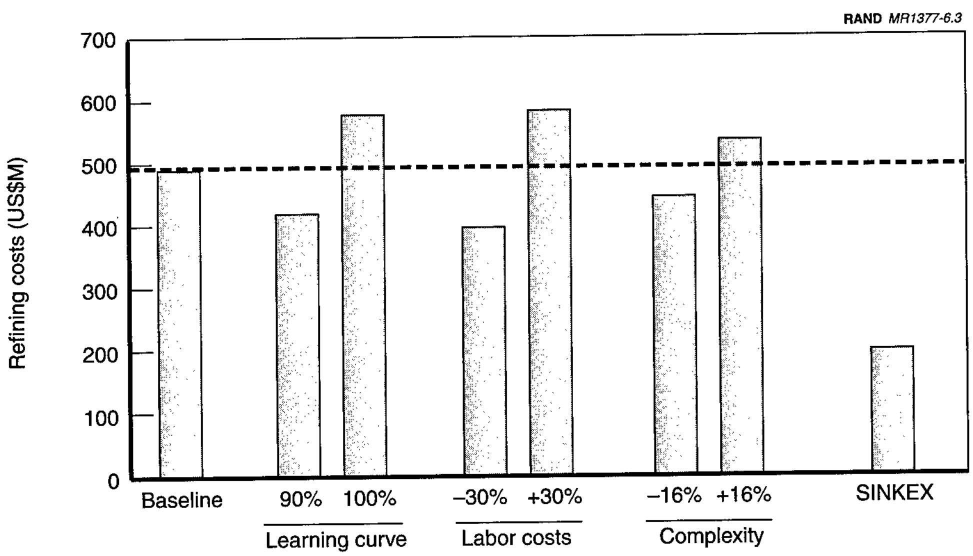

Figure 6.3—Sensitivities Within Reefing Costs

Reefing shares some learning experience sensitivities with domestic recycling, in this case with regard to the expectation that contractors will grow more efficient in preparing ships for reefing. However, because the reefing option is limited to 20 years and is based on a fairly extensive database of historic reefing preparation costs, it lacks the extreme sensitivity to variations in cost factors seen for the other options, variations that might explode and inflate the overall cost of those options much beyond our predictions. What could add to the predicted program cost for reefing is more-demanding new standards for reef preparation.

Reefing brings with it the potential for additional economic offsets in the form of benefits to communities: increased revenues from recreational diving, sport fishing, improved commercial fishing, and similar endeavors that prosper when reefing takes place in adjacent waters. As Chapter Five makes clear, there are two estimates for gross revenues from reefing: revenue per ship site and revenue per ship. Which estimate to use depends on whether ships are reefed singly or in groups. Nevertheless, the two estimates bound the possible outcomes. The average gross revenue per reef site is estimated at $2.7 million per year or $1.9 million per ship per year. Revenues accruing from taxes to state, federal, and local governments would build each year as the program proceeds, ultimately reaching between $68 and $170 million per year and continuing at that rate to the end of the reef system's lifetime. The growing tax revenue from the program would offset the program's total undiscounted average cost by as early as the twelfth year.

For the reefing option to succeed, a coordinated Navy-MARAD program will be needed. Given the demand for ships to use in reefing that is evident from the our surveys, there is likely to be strong competition for ships if a reefing program is announced. A way to ensure that the ships are equitably distributed will be needed. Also, one or both agencies will need a management program to handle expenditures and other details.

CONCLUSIONS

We did not attempt to identify the best solution for every individual ship in the 358-ship inventory. Our cost estimating techniques are accurate only for the aggregate of all 358 ships. Some ships, notably several in the MARAD inventory, are in very poor condition and may not be suitable for anything other than cautious and prompt recycling. Others may be unsuitable for one of the options because of size, military considerations, or some other specific issue. We therefore anticipate that a comprehensive program of disposal for all 358 ships will be some combination of domestic recycling, reefing, and intermediate storage.

The cost estimates for the reefing option are grounded in a sound set of cost data from other entities that have used reefing to dispose of unwanted vessels. Moreover, reefing is the only one of the options that has the potential to create revenue to the government (in the form of taxes from businesses associated with reef usage) beyond the ship-disposal costs the government will incur.

RECOMMENDATIONS

The Navy and MARAD should exploit the experience with the Navy's ongoing Ship Disposal Program to dispose of those inactive ships in the inventory that are in poor condition. This will reduce the current risk of sinking or some other environmentally notable incident. At the same time, both agencies should begin discussions between themselves and with the Environmental Protection Agency and coastal authorities aimed at developing standards and a program that will establish reefing as a viable course of action for disposal of as many of the 358 ships as possible. The goal should be to dispose of the current fleet by 2020 or earlier, as that conforms to a reasonable pace easily within the capacity of the available industrial base. Finally, no matter which option or combination of options is chosen, the Navy and MARAD should consider storing all of their inactive ships in MARAD facilities pending their disposal. That way they can take advantage of MARAD's lower annual storage costs.

Appendix A

THE FLEET FOR DISPOSAL

Table A.1 is the complete inventory of retired Navy and MARAD vessels—i.e., those vessels that are currently no longer needed for active or reserve service or will no longer be needed for such by the end of 2005. This table includes ships on lease to foreign governments, on loan to museums, and being held for spare parts or other purposes; it does not include ships to be retired after the year 2005. We assumed for this study that the rate at which ships will be retired from U.S. Navy service beyond 2005 will equal the consumption of such ships in military training exercises (SINKEX) plus their sale or donation for continued use elsewhere. Therefore, only those ships presently in the inventory or planned to enter it through 2005 were considered.

Some of the inactive ships listed in Table A.1 will not be disposed of by the Navy or MARAD during the foreseeable future for various reasons. When these ships are removed from the inventory, the result is the list shown in Table A.2, which is what we used for our cost estimates. Table A.2 is a working inventory assembled in November 2000. The appearance of any particular ship on this list does not necessarily mean that the cognizant government agency has authorized disposal of the ship or intends to do so in the near future. Table A.2 serves only as an approximation of the number and tonnage of Navy and MARAD ships that will require disposal over the next 20 years as best as could be determined in November 2000. Removals were based on the following criteria:

1. All museum ships (category N10). The Navy has no plans to withdraw any of these ships from their continued service as museums.
2. All ships on lease to foreign governments (category N2). The Navy is taking action to convert these leases to FMS so that the ships do not return to the Navy for disposal.
3. All ships designated by the Navy for use as targets in military training exercises (category N6).

4. Ten percent of the mobilization assets (category N1). This is the historic fraction of mobilization assets that are eventually sold or leased to foreign governments.
5. Twenty percent of the ships being held for potential FMS (category N3). This is the historic fraction of ships being held for potential FMS that are actually sold.
6. Ten percent of the ships being held for potential donation (category N4). This is the historic fraction of ships being held for potential donation that are actually donated for continued service elsewhere.

To meet criteria 4, 5, and 6, we arbitrarily struck specific ships in categories N1, N3, and N4 that added to the approximate tonnage and numbers of ships. All MARAD ships that appear in Table A.1 also appear in Table A.2. Thus, Table A.2 should be used only for determining the approximate number of ships (358) and tonnage of ships (2.8 million) for our analysis of the ship disposal options.

The following paragraphs provide specific details on the entries in Table A.1 (and thus those in Table A.2 as well).

NAVY VESSELS

Most of the Navy ships listed in Table A.1 are from the Navy's Ship Disposition Review Database of August 2000. This database includes all vessels (other than nuclear-powered submarines and surface ships) under the cognizance of a Navy activity that are no longer in active service in the U.S. Navy or that are in active service but are planned for decommission through the year 2013. Of the latter vessels, Table A.1 lists only those planned for decommission through the year 2005, because decommission plans beyond that date are highly speculative. Table A.1 also includes existing Navy museum ships and the Iowa Class battleships, which while not necessarily museums as of this writing, will be in the near future. We included museum ships not because the Navy advises that they are to be disposed of, but to provide a complete inventory of all retired assets.

Nuclear-powered submarines and surface ships were excluded because they are disposed of through an ongoing Navy program. Vessels transferred to non-Navy agencies, such as NOAA or the U.S. Air Force, were excluded because their ultimate disposal is the responsibility of the recipient agency. Small Navy boats and craft disposed of through the General Services Administration were also excluded; their disposal faces none of the difficulties connected to disposal of large vessels.

MARAD VESSELS

The MARAD vessels listed in Table A.1 come from MARAD's Reserve Fleet inventory of November 7, 1999. This inventory consists of all vessels for which MARAD has title or custody. Table A.1 includes all ships from this inventory that are specifically listed as "ready for disposal" or are in retention categories that MARAD agrees designate ships that may require disposal within 20 years, when a disposal program is set up. Table A.1 does not include MARAD Ready Reserve force ships presently operating or being indefinitely retained by MARAD.

DATA

Table A.1 contains 22 data entries for each vessel, many of which do not appear in Table A.2.

1. Number. This is an arbitrary unique number assigned to each entry in the table so that specific entries can be found easily.

2. Category. This is an alphanumeric entry in which the letter shows whether the ship originated as a Navy (N) or a MARAD (M) vessel. The Navy and MARAD are each responsible for a few ships that originated elsewhere, such as in the U.S. Coast Guard or another federal agency. In such cases, an M or an N is assigned based on which of the two agencies is presently responsible for the vessel. There are 12 possible categories, 10 for Navy-origin vessels and two for MARAD-origin vessels.

Navy Origin Vessels

N1: Mobilization and other retention assets. These are ships being retained by the Navy for recommissioning in the event of a national emergency.

N2: Existing foreign military leases. These are former Navy ships presently being operated by a foreign government under a military lease program.

N3: Potential future FMS and grants. These are ships designated for possible continued use by a foreign government.

N4: Potential donations or commercial leases. These are ships eligible for continued use domestically.

N5: Former Navy ships, title-transferred to MARAD for disposition. These are former Navy ships that are now the property of MARAD.

N6: SINKEX candidates. These are ships being retained by the Navy for potential use in military exercises.

N7: Held for spare parts. These are ships held by the Navy as sources of spare parts for operating Navy ships.

N8: Navy-title vessels, ready for disposal, held at Navy Inactive Ship Maintenance Facilities (NISMFs) or MARAD facilities. These are ships the Navy is ready to dispose of at this time.

N9: Special vessels. These are ships that the Navy retains responsibility for that do not fit in any of the first eight categories.

N10: Museum ships. These are ships that are now or will in the near future become public museums.

MARAD Origin Vessels

M1: Ready for disposal.

M2: In MARAD Inventory but unlikely to be retained.

To determine vessel origin, we used Silverstone.[1] Vessels listed in Silverstone as being constructed originally for service in the U.S. Navy are designated as Navy, or "N", vessels. Any vessel not listed in Silverstone but appearing on the cited Navy or MARAD inventories is designated as a MARAD, or "M", vessel.

3. Class/Type. This is the Navy ship class designation (such as FFG7) or the MARAD type designation (such as Dry Cargo).

4. Hull. This is the hull number (if any) that was assigned to the vessel when it was built. For example, USS *Wadsworth* has a hull number of FFG9 and a class description (previous column) of FFG7.

5. Name. This is the name by which the vessel is currently known. Note that several auxiliaries and MARAD vessels have had name changes during their lifetime.

6. Ship Type. For Navy vessels, this is a type designation assigned by RAND or taken from the source inventory. Type designations are AUX for auxiliary ship, SC for surface combatant, CV for aircraft carrier, AMP for amphibious warfare ship, MINE for mine warfare ship, SUB for nonnuclear submarine, BB for battleship, and OTH for other—i.e., a ship that does not fit in any of the preceding

[1]Paul H. Silverstone, *U.S. Warships Since 1945*, Naval Institute Press, 1986.

categories. For ships in the MARAD inventory, we retained the type designation assigned by MARAD.

7. Yr Built. This is the year the ship was delivered. These dates were obtained from the source databases or from Silverstone,[2] Couhat and Prexlin,[3] The ABS Record,[4] or Freidman.[5]

8. Yr Stricken or to Inact. This is the year the vessel was last removed from active service and placed in inactive status by the Navy or by MARAD. This date generally is not available for MARAD vessels, so Table A.1 is incomplete in this regard.

9 and 10. LT LSW and Estimated. Column 9 is the long tons (LT) of light ship weight (LSW). One long ton is 2,240 pounds; LSW is the total weight of a ship without cargo, fuel, crew or crew effects, and consumable stores and is very close to the total weight of a ship that would be offered to a ship recycler. Some military ships grow by 10 percent or more in LSW as they age because they have new war-fighting equipment added. The Navy keeps exact track of each vessel's LSW to ensure that ship righting moments and handling characteristics are kept within acceptable values. However, we judged it unnecessary to perform the difficult task of recovering exact LSWs from Navy or MARAD records for the purpose of this evaluation. Instead, we used initial design LSWs drawn from the sources cited in the footnotes. Thus the LSWs for Navy-origin vessels probably underestimate the actual weights of the ships listed. Commercial vessel records normally do not record LSW. After consulting with the American Bureau of Shipping, we derived LSWs by subtracting the recorded values for full load displacement (the long tons of water displaced by the ship when fully loaded) from the deadweight tonnage (the tons of cargo, fuel, people, personnel effects, and stores a ship can carry when fully loaded). Where no data were available to us, LSW was estimated from the LSW of similar ships. To indicate these cases, an "e" is entered in the Estimated column, column 10.

11. Prop System. This is the propulsion system employed in each ship. These data were taken from references cited above. Possible entries are DIESEL for propelled by a diesel engine(s) driving the propeller(s) through gears; DIESEL ELECT for propelled by diesel engines driving electric generators that provide

[2]Silverstone, 1986.

[3]Jean L. Couhat and Bernard Prexlin, *Combat Fleets of the World*, Naval Institute Press, 1986, 1989, or 1991.

[4]American Bureau of Ships Record, 1991.

[5]Norman Freidman, *U.S. Destroyers, An Illustrated Design History* (1982), *U.S. Aircraft Carriers, An Illustrated Design History* (1983), and *U.S. Battleships, An Illustrated Design History* (1984), Naval Institute Press.

power to an electric motor that drives the propeller(s); STM TUR for propelled by a steam turbine(s) driving the propeller(s) through gears; GAS TUR for propelled by a gas turbine(s) driving the propeller(s) through gears; CODAG for propelled by a combination of diesel and gas turbine engines driving the propeller(s) through gears; SAIL for propelled by sails; VTE for propelled by vertical triple expansion steam piston engines; NONE for no propulsion system; and no entry for no information found.

12 and 13. KSHP and #shafts. These are the total shaft horsepower (the power at the output shaft of the gear or motor providing the ship's motive power) of the vessel's propulsion system in 1000s of horsepower and the number of shafts in the propulsion system. (These are from the same sources cited above.) In some cases, the ship's power was available only as brake horsepower (power at the output of the main engines) or propeller horsepower (power delivered to the propeller). We took these all to be shaft horsepower since the differences among these parameters, while important to naval architecture, are small with regard to this evaluation.

14. T/KSHP. This is the LSW (in long tons) per shaft horsepower of ship in 1000s of horsepower. This parameter was used to guide the material estimates in Appendix B. Warships have very powerful engines and a low T/KSHP value, while merchant ships have small engines for their weight and a high T/KSHP.

15 and 16. MW Elect Pwr Gen and T/MW. These are the total megawatts of electric power generation for the ship's services and the long tons of LSW per megawatt of electrical power generated. These data were taken from the sources cited above. Not included in the MW figures is the MW of power from main propulsion engines in diesel-electric or steam turbine electric ships. T/KW is the tons of light ship weight per kilowatt of electric power generation. This parameter was developed to attempt to correlate T/KW with the amount of copper in the ship's electric system. The research team found no correlation, so the parameter was not used.

17 and 18. Storage Site and State. These are the city or locale where the ship is presently located (if not located overseas) and the state of that city/locale. These data were taken from the original source databases. They were used to estimate the cost of notional towing plans that would distribute all of the ships eligible for recycling almost equally to four notional U.S. recycling sites: two on the Atlantic Coast, one on the Gulf Coast, and one on the Pacific Coast. The data were also used to estimate towing costs for the overseas ship recycling option and the reefing option.

19, 20, and 21. Originator, Custodian, Title Holder. These are the vessel's original owner, its present custodian, and its present title holder. The three possible entries in each column are N for Navy, M for MARAD, and O for other

(such as the U.S. Coast Guard or a foreign government). We used these three criteria to sort the data. The originator data were used in our cost models to determine the value of recovered materials: Navy-origin ships have more scrap value than merchant ships because of their greater use of copper and other high-value alloys. The custodian data were used in the cost model to determine the cost of ship storage: Navy storage costs are significantly higher than MARAD storage costs. The title holder data told us which agency is responsible for ultimate disposal of the vessel. MARAD presently has title to many Navy-origin vessels whose titles were transferred to MARAD for disposal as required by law.[6] Conversely, MARAD facilities store many vessels for which the Navy retains title. This designator was used to evaluate how changes in the number of titles each agency held would impact each agency's budget for the ship disposal options.

22. PCBs. These are PCB data derived from four PCB analysis databases provided by NAVSEA 00T and from a 1997 MARAD report.[7] A yes (Y) indicates that samples of solid and liquid materials in the ship were taken and that materials containing 50 parts per million or more PCBs were found. A no (N) indicates that samples were taken and no materials containing 50 parts per million or more PCBs were found. A dash indicates that no samples were taken. Note that an entry of Y or N does not indicate that ship-to-ship sampling was uniform. Most N entries are for ships in which only liquids were sampled. Liquids (most often lubricants and hydraulic fluids) rarely contain PCBs above 50 parts per million. See Appendix C for a discussion of PCBs in ships.

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[6]The National Maritime Heritage Act of 1994 requires MARAD to dispose of unwanted vessels in the MARAD fleet by September 30, 2001 in a manner that maximizes financial return to the United States.

[7]MARAD, *Survey of Ships and Materials*, Report MA-ENV-820-96003-F, January 1997.

Table A.1

Navy and MARAD Retired Ship Assets

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
337	M1	T2-S/17K		ALBERT E. WATTS	T2-S/17K	1941		9,160								Mobile, AL	AL	M	M	M	-
338	M1	Cable Layer (1980)	AR	ALBERT J MYER	C S3S2	1946		4,410		DIESEL ELEC	4.0	2	1,103	7	678	James River (RF)	VA	M	M	M	-
339	M1	Dry Cargo	AK	AMERICAN RACER	C4-S	1964		8,067		STM TUR	18.8	1	429	3	3,227	Suisun Bay (RF)	CA	M	M	M	-
341	M1	Military Auxiliary	AK	ARTHUR M HUDDELL	EC2-	1943		4,500	e	STM TUR		1				James River (RF)	VA	M	M	M	-
342	M1	Dry Cargo	AK	BARNARD VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Suisun Bay (RF)	CA	M	M	M	-
343	M1	Buoy Tender	WAGL388	BASSWOOD	OTH	1943		935		DIESEL ELEC	1.2		779			Suisun Bay (RF)	CA	O	M	M	-
344	M1	Tanker	AOT	BEAUJOLAIS	PRVT	1954		7,832		STM TUR	13.8	1	568	1	9,790	Beaumont (RF)	TX	M	M	M	-
345	M1	Dry Cargo	AK	BUILDER	C3-S	1962		6,915		STM TUR	13.8	1	501	1	4,939	James River (RF)	VA	M	M	M	-
348	M1	Tanker	AOT	CONNECTICUT	PRVT	1958		9,960		STM TUR	20.6	1	483	1	9,960	Suisun Bay (RF)	CA	M	M	M	-
352	M1	Dry Cargo	AK	EARLHAM VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Suisun Bay (RF)	CA	M	M	M	-
353	M1	Dry Cargo	AK	EXPORT CHALLENGER	C3-S	1963		6,880		STM TUR	13.8	1	499	1	4,914	James River (RF)	VA	M	M	M	Y
355	M1	Buoy Tender	WAGL212	FIR	OTH	1939		989		DIESEL ELEC						Suisun Bay (RF)	CA	O	M	M	-
356	M1	Tanker	AOT	FLORENCE	PRVT	1954		7,881		STM TUR	13.8	1	571	1	7,881	Suisun Bay (RF)	CA	M	M	M	-
364	M1	Tanker	AOT	GETTYSBURG	PRVT	1957		12,520		STM TUR	26.5	1	472	2	8,347	Suisun Bay (RF)	CA	M	M	M	-
365	M1	Dry Cargo	AK	HANNIBAL VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Suisun Bay (RF)	CA	M	M	M	-
366	M1	Dry Cargo	AK	HATTIESBURG VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Beaumont (RF)	TX	M	M	M	-
367	M1	Buoy Tender	WAGL395	IRIS	OTH	1943		935		DIESEL ELECT	1.2		779			Suisun Bay (RF)	CA	O	M	M	-
368	M1	Military Auxiliary	LP	LAUDERDALE	VC2-	1944		4,551		STM TUR	9.4	1	484	1	7,585	James River (RF)	VA	M	M	M	-
369	M1	Military Auxiliary	AK	MARINE FIDDLER	C4-S	1945		6,646		STM TUR	9.9	1	671	1	7,384	James River (RF)	VA	M	M	M	-
370	M1	Tanker	AOT	MEACHAM	PRVT	1957		8,315		STM TUR	15.0	1	554	1	10,394	Beaumont (RF)	TX	M	M	M	-
374	M1	Dry Cargo	AK	MORMACDAWN	C4-S	1965		4,493		STM TUR	18.8	1	239	3	1,797	James River (RF)	VA	M	M	M	-
375	M1	Dry Cargo	AK	MORMACMOON	C4-S	1965		4,493		STM TUR	18.8	1	239	3	1,797	James River (RF)	VA	M	M	M	-
376	M1	Tanker	AOT	NAECO	PRVT	1957		8,300		STM TUR	15.0	1	553	1	10,375	Beaumont, TX	TX	M	M	M	-
377	M1	Cable Layer (1978)	AR	NEPTUNE	C S3S2	1946		3,423		DIESEL ELEC	4.0	2	856	6	571	James River (RF)	VA	M	M	M	N
378	M1	Dry Cargo	AK	OCCIDENTAL VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Suisun Bay (RF)	CA	M	M	M	-
380	M1	Buoy Tender	WAGL307	PLANETREE	OTH	1943		935		DIESEL ELEC	1.2		779			Suisun Bay (RF)	CA	O	M	M	-
383	M1	Dry Cargo		PVT FRED C. MURPHY	VC2-S-AP3	1945		4,500		STM TUR	6.6		682			Beaumont (RF)	TX	M	M	M	-
384	M1	Dry Cargo	AK	QUEENS VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Suisun Bay (RF)	CA	M	M	M	-
385	M1	Dry Cargo	AK	RIDER VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Suisun Bay (RF)	CA	M	M	M	-
387	M1	Dry Cargo	AK	SANTA CRUZ	C4-S	1966		9,099		STM TUR	15.5	1	587	3	3,033	James River (RF)	VA	M	M	M	-
388	M1	Dry Cargo	AK	SANTA ELENA	C4-S	1967		9,052		STM TUR	15.5	1	584	3	3,017	James River (RF)	VA	M	M	M	-
389	M1	Dry Cargo	AK	SANTA ISABEL	C4-S	1967		9,052		STM TUR	15.5	1	584	3	3,017	James River (RF)	VA	M	M	M	-
391	M1	Dry Cargo	AK	SIOUX FALLS VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	0	45,180	Suisun Bay (RF)	CA	M	M	M	-
392	M1	Transport & Pass-Cargo	AP	STATE	P2-S	1952		11,200		STM TUR	13.5	1	830	2	6,222	James River (RF)	VA	M	M	M	-
394	M1	Transport & Pass-Cargo	AP	TEXAS CLIPPER (I)	P1-S	1944		7,662		STM TUR	8.8	1	871	1	8,513	Beaumont (RF)	TX	M	M	M	-
399	M1	Dry Cargo	AK	WASHINGTON	V T2-S	1944		6,840		STM TUR ELEC	10.0	1	684	1	8,550	James River (RF)	VA	M	M	M	-
400	M1	Dry Cargo	AK	WAYNE VICTORY	VC2-	1945		4,481		STM TUR	6.6	1	679	0	44,810	James River (RF)	VA	M	M	M	Y
401	M1	Dry Cargo	AK	WINTHROP VICTORY	VC2-	1945		4,481		STM TUR	6.6	1	679	0	44,810	Suisun Bay (RF)	CA	M	M	M	-
412	M1	Dry Cargo	AK	AMERICAN RANGER	C4-S	1965		7,545		STM TUR	18.8	1	401	3	3,018	James River (RF)	VA	M	M	M	-
456	M1	Dry Cargo	AKV	MAINE	T2-S	1944		8,928		STM TUR ELEC	10.0	1	893	1	11,160	Beaumont (RF)	TX	M	M	M	-
164	M2	WAGB4	WAGB4	GLACIER	OTH	1953		6,406		DIESEL ELEC	21		305			Suisun Bay (RF)	CA	O	M	M	-
402	M2	Tanker	AOT	ADONIS	FORN	1966		17,994		DIESEL	20.7	1	869	2	10,585	Beaumont (RF)	TX	N	M	M	-
403	M2	Dry Cargo	AK	ADVENTURER	C3-S	1960		6,584		STM TUR	13.8	1	477	2	4,389	Suisun Bay (RF)	CA	M	M	M	-
404	M2	Dry Cargo	AK	AGENT	C3-S	1961		6,481		STM TUR	13.8	1	470	2	4,321	Suisun Bay (RF)	CA	M	M	M	-
405	M2	Dry Cargo	AK	AIDE	C3-S	1961		6,481	e	STM TUR	13.8	1	470	2	4,321	Suisun Bay (RF)	CA	M	M	M	-

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
407	M2	Dry Cargo	AK	ALLISON LYKES	C4-S	1964		7,307		STM TUR	19.0	1	385	1	6,089	Beaumont (RF)	TX	M	M	M	-
408	M2	Dry Cargo	AK	AMBASSADOR	C3-S	1960		6,584		STM TUR	13.8	1	477	2	4,389	Suisun Bay (RF)	CA	M	M	M	-
409	M2	Dry Cargo	ACS	AMERICAN BANKER	C6-S	1962		10,048		STM TUR	22.0	1	457	2	4,369	James River (RF)	VA	M	M	M	-
411	M2	Tanker		AMERICAN OSPREY	Stm/34K	1958		10,117		STM TUR	15.0		674	1	10,117	Beaumont (RF)	TX	M	M	M	-
413	M2	Dry Cargo	AK	AMERICAN RELIANCE	C4-S	1965		7,545		STM TUR	18.8	1	401	3	3,018	Suisun Bay (RF)	CA	M	M	M	-
414	M2	Dry Cargo		BANNER	C3-S-46a	1961		6,771		STM TUR	13.8		491	1	4,836	Beaumont (RF)	TX	M	M	M	-
415	M2	Dry Cargo	AK	BAY	C3-S	1961		6,844		STM TUR	13.8	1	496	1	4,889	Suisun Bay (RF)	CA	M	M	M	-
416	M2	Dry Cargo	AKR	BAYAMON	PRVT	1970		10,226		STM TUR	32.0	1	320	3	4,090	James River (RF)	VA	M	M	M	-
417	M2	Dry Cargo	AK	BRINTON LYKES	C5-S	1962		8,606		STM TUR	11.0	1	782	1	7,172	Beaumont (RF)	TX	M	M	M	-
418	M2	Dry Cargo	AK	BUYER	C3-S	1962		6,875		STM TUR	13.8	1	498	1	4,911	Beaumont (RF)	TX	M	M	M	-
419	M2	Dry Cargo		CAPE ALAVA	C4-S-58a	1962		7,382	e	STM TUR	18.2		406	2	4,101	James River (RF)	VA	M	M	M	-
420	M2	Dry Cargo		CAPE BON	C4-S-66a	1967		7,178		STM TUR	15.5		463	2	4,785	Suisun Bay (RF)	CA	M	M	M	-
421	M2	Dry Cargo	AK	CAPE CANAVERAL	C3-S	1964		5,876		STM TUR	16.9	1	348	1	4,897	James River (RF)	VA	M	M	M	-
422	M2	Dry Cargo	AK	CAPE CANSO	C3-S	1963		5,876		STM TUR	11.0	1	534	1	4,897	James River (RF)	VA	M	M	M	-
423	M2	Dry Cargo	AK	CAPE CARTHAGE	C3-S	1963		5,876		STM TUR	16.9	1	348	1	4,897	James River (RF)	VA	M	M	M	-
424	M2	Dry Cargo		CAPE CATAWBA	C3-S-33a	1961		5,965		STM TUR	12.1		493	1	4,971	Cheatham Annex	VA	M	M	M	-
425	M2	Dry Cargo	AK	CAPE CATOCHE	C3-S	1963		5,876		STM TUR	16.9	1	348	1	4,897	James River (RF)	VA	M	M	M	-
426	M2	Dry Cargo		CAPE CHALMERS	C3-S-37c	1963		5,918		STM TUR	11.0		538	1	4,932	James River (RF)	VA	M	M	M	-
427	M2	Dry Cargo	AK	CAPE CHARLES	C3-S	1963		5,876		STM TUR	11.0	1	534	1	4,897	James River (RF)	VA	M	M	M	-
428	M2	Dry Cargo	AK	CAPE CLEAR	C3-S	1963		5,876		STM TUR	11.0	1	534	1	4,897	James River (RF)	VA	M	M	M	-
431	M2	RoRo		CAPE LAMBERT	Dsl/Canada	1973		10,155		DIESEL	17.0		597	3	3,761	Wilmington, NC	NC	M	M	M	-
432	M2	RoRo		CAPE LOBOS	Dsl/Canada	1972		10,503		DIESEL	17.0		618	3	3,890	Wilmington, NC	NC	M	M	M	-
433	M2	Combination		CAPE NOME	C5-S-78a	1969		12,286		STM TUR	30.0		410	3	4,095	James River (RF)	VA	M	M	M	-
434	M2	Dry Cargo	AK	CATAWBA VICTORY	VC2-	1945		4,518		STM TUR	6.6	1	685	1	6,454	James River (RF)	VA	M	M	M	-
436	M2	RoRo		COMET	C3-ST-14	1958		8,175		STM TUR	13.2		619	1	6,813	Alameda, CA	CA	M	M	M	-
437	M2	Dry Cargo		COURIER	C3-S-46b	1962		6,700		STM TUR	13.8		486	1	4,786	Beaumont (RF)	TX	O	M	M	-
438	M2	Dry Cargo	AK	DAWN	C4-S	1963		7,307	e	STM TUR	18.2	1	401	2	4,059	Suisun Bay (RF)	CA	M	M	M	-
439	M2	Dry Cargo	AK	DEL MONTE	C3-S	1968		6,246	e	STM TUR	11.7	1	534	2	3,123	James River (RF)	VA	M	M	M	-
440	M2	Dry Cargo	AK	DEL VALLE	C3-S	1968		6,246		STM TUR	11.7	1	534	2	3,123	Beaumont (RF)	TX	M	M	M	-
441	M2	Dry Cargo	AK	DEL VIENTO	C3-S	1968		6,246		STM TUR	11.7	1	534	2	3,123	Beaumont (RF)	TX	M	M	M	-
442	M2	Tanker	AOT	FALCON LEADER	T6-M	1983		11,200	e	DIESEL	15.0	1	747	1	11,200	Beaumont (RF)	TX	M	M	M	-
443	M2	Dry Cargo		GULF BANKER	C3-S-37d	1964		5,843		STM TUR	11.0		531	1	4,869	Beaumont (RF)	TX	M	M	M	-
444	M2	Dry Cargo	AK	GULF FARMER	C3-S	1964		5,843		STM TUR	11.0	1	531	1	4,869	Beaumont (RF)	TX	M	M	M	-
445	M2	Dry Cargo	AK	GULF MERCHANT	C3-S	1965		5,843		STM TUR	11.0	1	531	1	4,869	Beaumont (RF)	TX	M	M	M	-
446	M2	Dry Cargo	AK	GULF SHIPPER	C3-S	1964		5,843		STM TUR	11.0	1	531	1	4,869	Beaumont (RF)	TX	M	M	M	-
447	M2	Dry Cargo		GULF TRADER	C3-S-37d	1964		5,842		STM TUR	11.0		531	1	4,868	Beaumont (RF)	TX	M	M	M	-
450	M2	Dry Cargo	AK	JAMES MCHENRY	C1-M	1979		2,827		DIESEL	5.8	2	487	1	2,827	James River (RF)	VA	M	M	M	-
452	M2			LAKE	C3-S-33a	1961		5,865		STM TUR	12.1		485	1	4,888	James River (RF)	VA	M	M	M	-
453	M2	Tanker	AOT	LEXINGTON	PRVT	1958		12,483		STM TUR	26.5	1	471	3	4,027	Beaumont (RF)	TX	M	M	M	-
454	M2	Dry Cargo	AK	LINCOLN	C4-S	1961		8,386		STM TUR	19.3	1	435	1	5,990	Suisun Bay (RF)	CA	M	M	M	-
455	M2	Dry Cargo	AK	MAGALLANES	C4-S	1964		7,307		STM TUR	19.0	1	385	2	4,871	Beaumont (RF)	TX	M	M	M	-
457	M2	Dry Cargo	AK	MALLORY LYKES	C4-S	1965		7,307		STM TUR	19.0	1	385	2	4,871	Beaumont (RF)	TX	M	M	M	-
459	M2	Tanker	AOT	MARYLAND	PRVT	1963		7,105		STM TUR		1				Beaumont (RF)	TX	M	M	M	-
465	M2	Tanker		MOUNT VERNON	Stm/49K	1961		12,929		STM TUR	15.0		862	2	8,619	Beaumont (RF)	TX	N	M	M	N
466	M2	Tanker		MOUNT WASHINGTON	Stm/50K	1963		13,373		STM TUR	21.5		622	1	11,144	Houston, TX	TX	M	M	M	-

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
468	M2	Dry Cargo		NORTHERN LIGHT	C3-S-33a	1961		5,965		STM TUR	12.1		493	1	4,971	Suisun Bay (RF)	CA	N	M	M	-
469	M2	Dry Cargo	AKV	OHIO	T2-S	1944		8,947		STM TUR ELEC	10.0	1	895	1	11,184	Beaumont (RF)	TX	M	M	M	-
470	M2	Dry Cargo	AK	PAN AMERICAN VICTORY	VC2-	1945		4,481		STM TUR	6.6	1	679	0	44,810	Suisun Bay (RF)	CA	M	M	M	-
471	M2	Transport & Pass-Cargo	AP	PATRIOT STATE	S5-S	1964		10,565		STM TUR	19.8	1	534	2	4,593	James River (RF)	VA	M	M	M	-
472	M2	Tanker	AOT	PENNSYLVANIA TRADER	PRVT	1962		8,728		STM TUR	13.8	1	632	1	7,273	Beaumont (RF)	TX	M	M	M	-
473	M2	Dry Cargo		PIONEER COMMANDER	C4-S-57a	1963		7,518		STM TUR	22.5		334	3	3,007	Beaumont (RF)	TX	M	M	M	-
474	M2			PIONEER CONTRACTOR	C4-S-57a	1963		7,518		STM TUR	22.5		334	3	3,007	Beaumont (RF)	TX	M	M	M	-
475	M2	Dry Cargo	AK	PIONEER CRUSADER	C4-S	1963		7,513		STM TUR	22.5	1	334	3	3,005	Beaumont (RF)	TX	M	M	M	-
476	M2	Dry Cargo	AK	PRESIDENT	C4-S	1961		8,386		STM TUR	19.3	1	435	1	5,990	Suisun Bay (RF)	CA	M	M	M	-
477	M2	Dry Cargo	AK	PRIDE	C3-S	1960		5,963		STM TUR	12.1	1	493	1	4,969	James River (RF)	VA	M	M	M	-
478	M2	Tanker	AOT	PRIDE II	PRVT	1959		8,881		STM TUR	15.0	1	592	2	5,921	Beaumont (RF)	TX	M	M	M	-
479	M2	Tanker	AOC	SAGAMORE	PRVT	1959		1,172		DIESEL	1.7	1	689	1	2,344	Suisun Bay (RF)	CA	M	M	M	-
480	M2	Dry Cargo	AK	SANTA LUCIA	C4-S	1966		9,037		STM TUR	15.5	1	583	3	3,012	James River (RF)	VA	M	M	M	-
481	M2			SCAN	C3-S-33a	1961		5,965		STM TUR	12.1		493	1	4,971	James River (RF)	VA	M	M	M	-
482	M2	Dry Cargo	AK	SHIRLEY LYKES	C5-S	1962		8,606		STM TUR	11.0	1	782	1	7,172	James River (RF)	VA	M	M	M	Y
484	M2	Dry Cargo	AK	SOLON TURMAN	C5-S	1961		8,605		STM TUR	9.9	1	869	1	7,171	Suisun Bay (RF)	CA	M	M	M	-
486	M2	Passenger Ship	AGS	STATE OF MAINE	P2-S1-DN3	1952	1990	7,900		STM TUR	1		2		500	James River (RF)	VA	M	M	M	-
487	M2	Passenger Ship	AGS	TEXAS CLIPPER II	P1-S1-DR	1944	1970	3,200		DIESEL	1				450	Beaumont (RF)	TX	M	M	M	-
1	N1	AD37	AD38	PUGET SOUND	AUX	1966	1996	13,600		STM TUR	20	1	680	12	1,133	NISMF	PA	N	N	N	N
2	N1	AD37	AD42	ACADIA	AUX	1979	1994	13,600		STM TUR	20	1	680	12	1,133	NISMF	HI	N	N	N	-
3	N1	AS33	AS33	SIMON LAKE	AUX	1964	1999	20,500		STM TUR	20	1	1,025	11	1,864			N	N	N	-
4	N1	AS36	AS41	MCKEE	AUX	1980	1999	13,840		STM TUR	20	1	692	11	1,258			N	N	N	-
6	N1	DD963	DD966	HEWITT	SCA	1974	2004	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	-
13	N1	DD963	DD980	MOOSBRUGER	SCA	1977	2001	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	-
14	N1	DD963	DD981	JOHN HANCOCK	SCA	1977	2001	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	-
16	N1	CV59	CV61	RANGER	CV	1956	1993	54,600		STM TUR	280	4	49	16	3,370	NISMF	WA	N	N	N	-
17	N1	CV59	CV62	INDEPENDENCE	CV	1958	1998	54,600		STM TUR	280	4	49	16	3,370			N	N	N	-
18	N1	CV63	CV64	CONSTELLATION	CV	1960	2003	56,300		STM TUR	280	4	50	17	3,412	ACTIVE		N	N	N	-
19	N1	LKA113	LKA113	CHARLESTON	AMP	1967	1992	13,727		STM TUR	22	1	624			NISMF	VA	N	N	N	-
20	N1	LKA113	LKA114	DURHAM	AMP	1968	1994	13,727		STM TUR	22	1	624			NISMF	HI	N	N	N	-
21	N1	LKA113	LKA115	MOBILE	AMP	1968	1994	13,727		STM TUR	22	1	624			NISMF	PA	N	N	N	-
22	N1	LKA113	LKA116	ST LOUIS	AMP	1969	1992	13,727		STM TUR	22	1	624			NISMF	HI	N	N	N	-
23	N1	LKA113	LKA117	EL PASO	AMP	1969	1994	13,727		STM TUR	22	1	624			NISMF	PA	N	N	N	-
24	N1	LST1179	LST1182	FRESNO	AMP	1968	1993	4,750		DIESEL	16	2	148			NISMF	HI	N	N	N	-
25	N1	LST1179	LST1187	TUSCALOOSA	AMP	1969	1994	4,750		DIESEL	16	2	148			NISMF	HI	N	N	N	-
26	N1	LST1179	LST1190	BOULDER	AMP	1970	1994	4,750		DIESEL	16	2	148			NISMF	VA	N	N	N	-
27	N1	LST1179	LST1191	RACINE	AMP	1970	1993	4,750		DIESEL	16	2	148			NISMF	HI	N	N	N	-
28	N1	AFS1	AFS1	MARS	AUX	1962	1993	9,200		STM TUR	22	1	418	5	1,917	NISMF	HI	N	N	N	-
29	N1	AFS1	AFS6	SAN DIEGO	AUX	1969	1993	9,200		STM TUR	22	1	418	5	1,917	NISMF	PA	N	N	N	-
30	N1	AO187	AO188	JOSHUA HUMPHREYS	AUX	1987	1996	39,400		DIESEL ELEC	32	2	616	11	3,717	NISMF	PA	N	N	N	-
31	N1	AO187	AO190	ANDREW HIGGINS	AUX	1987	1996	39,400		DIESEL	32	2	616	11	3,717	Suisun Bay (RF)	CA	N	M	N	-
32	N2	DE1040	DE1041	BRADLEY	SCA	1964	1988	2,620		STM TUR	35	1	75	2	1,310	OVERSEAS		N	O	N	-
33	N2	DE1040	DE1045	DAVIDSON	SCA	1964	1988	2,620		STM TUR	35	1	75	2	1,310	OVERSEAS		N	O	N	-
34	N2	DE1040	DE1048	SAMPLE	SCA	1964	1988	2,620		STM TUR	35	1	75	2	1,310	OVERSEAS		N	O	N	-
35	N2	DE1040	DE1050	ALBERT DAVID	SCA	1964	1989	2,620		STM TUR	35	1	75	2	1,310	OVERSEAS		N	O	N	-

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
36	N2	DE1052	DE1056	CONNOLE	SCA	1968	1992	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
37	N2	DE1052	DE1063	REASONER	SCA	1970	1993	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
38	N2	DE1052	DE1068	VREELAND	SCA	1969	1992	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
39	N2	DE1052	DE1073	ROBERT E PEARY	SCA	1971	1992	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
40	N2	DE1052	DE1075	TRIPPE	SCA	1969	1992	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
41	N2	DE1052	DE1076	FANNING	SCA	1970	1993	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
42	N2	DE1052	DE1083	COOK	SCA	1971	1992	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
43	N2	DE1052	DE1086	BREWTON	SCA	1971	1992	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
44	N2	DE1052	DE1087	KIRK	SCA	1971	1993	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
45	N2	DE1052	DE1088	BARBEY	SCA	1971	1992	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
46	N2	DE1052	DE1092	THOMAS C HART	SCA	1972	1993	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
47	N2	DE1052	DE1093	CAPODANNO	SCA	1972	1993	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
48	N2	DE1052	DE1078	JOSEPH HEWES	SCA	1970	1994	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
49	N2	DE1052	DE1084	MCCANDLESS	SCA	1971	1994	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
50	N2	DE1052	DE1085	DONALD B BEARY	SCA	1971	1994	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
52	N2	LST1179	LST1180	MANITOWOC	AMP	1969	1993	4,750		DIESEL	16	2	148			OVERSEAS		N	O	N	-
53	N2	LST1179	LST1181	SUMTER	AMP	1969	1993	4,750		DIESEL	16	2	148			OVERSEAS		N	O	N	-
54	N2	LST1179	LST1186	CAYUGA	AMP	1969	1994	4,750		DIESEL	16	2	148			OVERSEAS		N	O	N	-
55	N2	LST1179	LST1189	SAN BERNADINO	AMP	1970	1995	4,750		DIESEL	16	2	148			OVERSEAS		N	O	N	-
56	N2	LST1179	LST1196	HARLAN COUNTY	AMP	1971	1995	4,750		DIESEL	16	2	148			OVERSEAS		N	O	N	-
57	N2	LST1179	LST1197	BARNSTABLE COUNTY	AMP	1971	1994	4,750		DIESEL	16	2	148			OVERSEAS		N	O	N	-
75	N2	FFG7	FFG19	JOHN A MOORE	SCA	1979	2000	2,750		GAS TUR	40	1	69	3	917	ACTIVE		N	N	N	N
76	N2	FFG7	FFG21	FLATELY	SCA	1980	1996	2,750		GAS TUR	40	1	69	3	917	OVERSEAS		N	O	N	-
82	N2	DE1052	DE1079	BOWEN	SCA	1970	1994	3,011		STM TUR	35	1	86	3	1,004	OVERSEAS		N	O	N	-
85	N2	LSD28	LSD33	ALAMO	AMP	1956	1990	6,800		STM TUR	24	2	142			OVERSEAS		N	O	N	-
86	N2	LSD28	LSD34	HERMITAGE	AMP	1956	1989	6,800		STM TUR	24	2	142			OVERSEAS		N	O	N	-
10	N3	DD963	DD973	JOHN YOUNG	SCA	1976	2004	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	-
58	N3	AD14	AD19	YOSEMITE	AUX	1943	1994	9,450		STM TUR	12	2	394	4	2,305	James River (RF)	VA	N	M	N	Y
59	N3	ARS5	ARS39	CONSERVER	AUX	1945	1994	1,530		DIESEL ELEC	2	2	319			NISMF	HI	N	N	N	Y
60	N3	ARS5	ARS40	HOIST	AUX	1945	1994	1,530		DIESEL ELEC	2	2	319			NISMF	VA	N	N	N	-
65	N3	DDG993	DDG993	KIDD	SCA	1979	1998	6,210		GAS TUR	80	2	39	6	1,035	NISMF	PA	N	N	N	N
66	N3	DDG993	DDG994	CALLAGHAN	SCA	1980	1998	6,210		GAS TUR	80	2	39	6	1,035	NISMF	WA	N	N	N	-
67	N3	DDG993	DDG995	SCOTT	SCA	1980	1998	6,210		GAS TUR	80	2	39	6	1,035	NISMF	PA	N	N	N	-
68	N3	DDG993	DDG996	CHANDLER	SCA	1980	1999	6,210		GAS TUR	80	2	39	6	1,035	ACTIVE		N	N	N	-
69	N3	FFG7	FFG9	WADSWORTH	SCA	1978	2002	2,750		GAS TUR	40	1	69	3	917	ACTIVE		N	N	N	-
71	N3	FFG7	FFG12	GEORGE PHILIP	SCA	1978	2003	2,750		GAS TUR	40	1	69	3	917	ACTIVE		N	N	N	N
72	N3	FFG7	FFG13	SAMUEL E. MORISON	SCA	1979	2003	2,750		GAS TUR	40	1	69	3	917	ACTIVE		N	N	N	-
73	N3	FFG7	FFG14	JOHN H SIDES	SCA	1979	2003	2,750		GAS TUR	40	1	69	3	917	ACTIVE		N	N	N	-
74	N3	FFG7	FFG15	ESTOCIN	SCA	1979	2002	2,750		GAS TUR	40	1	69	3	917	ACTIVE		N	N	N	Y
78	N3	DE1052	DE1062	WHIPPLE	SCA	1968	1992	3,011		STM TUR	35	1	86	3	1,004	NISMF	HI	N	N	N	-
87	N3	LSD36	LSD36	ANCHORAGE	AMP	1968	2005	8,600		STM TUR	24	2	179			ACTIVE		N	N	N	-
90	N3	LST1179	LST1179	NEWPORT	AMP	1968	1992	4,750		DIESEL	16	2	148			NISMF	VA	N	N	N	N
91	N3	LST1179	LST1183	PEORIA	AMP	1968	1994	4,750		DIESEL	16	2	148			NISMF	HI	N	N	N	-
92	N3	LST1179	LST1185	SCHENECTADY	AMP	1969	1993	4,750		DIESEL	16	2	148			NISMF	HI	N	N	N	-
93	N3	LST1179	LST1195	BARBOUR COUNTY	AMP	1971	1992	4,750		DIESEL	16	2	148			NISMF	HI	N	N	N	-

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
96	N3	TAGS26	TAGS27	KANE	AUX	1965	2001	1,935		DIESEL ELEC	4	1	538	1	1,935	ACTIVE		N	N	N	-
121	N3	AO177	AO179	MERRIMACK	AUX	1980	1998	8,210		STM TUR	24	1	342	8	989	James River (RF)	VA	N	M	N	Y
491	N3	DD963	DD969	PETERSON	SCA	1977	2004	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	
97	N4	CV59	CV59	FORRESTAL	CV	1954	1993	54,600		STM TUR	280	4	49	16	3,370	NISMF	PA	N	N	N	Y
98	N4	CA134	CA134	DES MOINES	SCA	1946	1961	17,000		STM TUR	120	4	35			NISMF	PA	N	N	N	-
99	N4	CG26	CG31	STERETT	SCA	1964	1994	5,340		STM TUR	85	2	31	7	785	Suisun Bay (RF)	CA	N	M	N	-
100	N4	CV59	CV60	SARATOGA	CV	1955	1994	54,600		STM TUR	280	4	49	16	3,370	NEWPORT	RI	N	N	N	N
101	N4	CV41	CV41	MIDWAY	CV	1945	1992	48,950		STM TUR	212	4	58	12	4,184	NISMF	WA	N	N	N	-
102	N4	DD963	DD979	CONOLLY	SCA	1977	1998	5,830		GAS TUR	80	2	36	6	972	NISMF	PA	N	N	N	-
103	N4	DDG2	DDG02	CHARLES F ADAMS	SCA	1959	1990	3,640		STM TUR	70	2	26	2	1,655	NISMF	PA	N	N	N	Y
104	N4	DE1052	DE1052	KNOX	SCA	1966	1992	3,011		STM TUR	35	1	86	2	1,506	NISMF	WA	N	N	N	-
105	N4	FFG7	FFG7	OLIVER HAZARD PERRY	SCA	1976	1997	2,750		GAS TUR	40	1	69	3	917	NISMF	PA	N	N	N	-
106	N4	LPD4	LPD4	AUSTIN	AMP	1964	2004	9,700		STM TUR	24	2	202	4	2,694	ACTIVE		N	N	N	-
107	N4	LPH2	LPH11	NEW ORLEANS	AMP	1960	1997	10,722		STM TUR	22	1	487	7	1,650	Suisun Bay (RF)	CA	N	M	N	-
109	N4	TUGBOAT	YTM146	HOGA	AUX	1941		260		DIESEL	1	1	325			Suisun Bay (RF)	CA	N	M	N	-
143	N4	LST1177	LST1171	LORAIN COUNTY	AMP	1958	1994	4,164		DIESEL	14		289			James River (RF)	VA	N	M	N	-
145	N4	AGOS1	AGOS4	TRIUMPH	AUX	1984	1995	2,285		DIESEL	3	2	357	2	1,143	Suisun Bay (RF)	CA	N	M	N	-
178	N4	EX LST963	ARL24	SPHINX	AUX	1944	1977	1,653		DIESEL	2		972			James River (RF)	VA	N	M	N	-
266	N4	TAO187	TAO191	BENJAMIN ISHERWOOD	AUX	1988	1997	9,500		DIESEL	33		292			James River (RF)	VA	N	M	M	-
267	N4	TAO187	TAO192	HENRY ECKFORD	AUX	1989	1997	9,500		DIESEL	33		292			James River (RF)	VA	N	M	N	-
334	N4	AFDM1	AFDM2	AFDM 2	OTH	1942		6,400		NONE						Beaumont (RF)	TX	N	M	M	-
335	N4	ARDM1	ARDM2	ALAMOGORDO	OTH	1944		5,200		NONE						James River (RF)	VA	N	M	M	Y
336	N4	Navy Drydock		SAN ONOFRE	OTH	1944		5,200	e							Suisun Bay (RF)	CA	N	M	M	-
89	N5	LSD36	LSD40	FORT FISHER	AMP	1972	1998	8,600		STM TUR	24	2	179			Suisun Bay (RF)	CA	N	M	N	-
110	N5	AE21	AE21	SURIBACHI	AUX	1955	1994	7,470		STM TUR	16	1	467	13	593	NISMF	PA	N	N	M	-
111	N5	AE21	AE24	PYRO	AUX	1958	1994	7,470		STM TUR	16	1	467			NISMF	WA	N	N	M	-
112	N5	AE21	AE29	MOUNT HOOD	AUX	1971	1999	7,470		STM TUR	16	1	467	6	1,358	ACTIVE		N	M	M	-
113	N5	AD37	AD37	SAMUEL GOMPERS	AUX	1966	1995	13,600		STM TUR	20	1	680	12	1,133	NISMF	VA	N	N	M	-
114	N5	AD37	AD41	YELLOWSTONE	AUX	1979	1996	13,600		STM TUR	20	1	680	12	1,133		VA	N	N	M	N
115	N5	AD37	AD43	CAPE COD	AUX	1980	1995	13,600		STM TUR	20	1	680	12	1,133	James River (RF)	VA	N	N	M	-
116	N5	AD37	AD44	SHENANDOAH	AUX	1982	1996	13,600		STM TUR	20	1	680	12	1,133		VA	N	N	M	N
117	N5	AFS1	AFS2	SYLVANIA	AUX	1963	1994	9,200		STM TUR	22	1	418	5	1,917	NISMF	PA	N	N	M	-
118	N5	AFS1	AFS4	WHITE PLAINS	AUX	1966	1995	9,200		STM TUR	22	1	418	5	1,917	NISMF	PA	N	N	M	-
119	N5	AO177	AO177	CIMARRON	AUX	1979	1998	8,210		STM TUR	24	1	342	8	989	Suisun Bay (RF)	CA	N	M	M	-
120	N5	AO177	AO178	MONONGAHELA	AUX	1979	1999	8,210		STM TUR	24	1	342	8	989	James River (RF)	VA	N	M	M	N
122	N5	AO177	AO180	WILLAMETTE	AUX	1981	1999	8,210		STM TUR	24	1	342	8	989	Suisun Bay (RF)	CA	N	M	M	-
123	N5	AO177	AO186	PLATTE	AUX	1982	1999	8,210		STM TUR	24	1	342	8	989	James River (RF)	VA	N	M	M	-
125	N5	AOR1	AOR3	KANSAS CITY	AUX	1969	1994	12,500		STM TUR	32	2	195	8	1,563	NISMF	WA	N	N	M	-
126	N5	AOR1	AOR4	SAVANNAH	AUX	1970	1995	12,500		STM TUR	32	2	195	8	1,563	James River (RF)	VA	N	M	M	-
127	N5	AOR1	AOR6	KALAMAZOO	AUX	1972	1996	12,500		STM TUR	32	2	195	8	1,563	James River (RF)	VA	N	N	M	N
128	N5	APA128	APA168	GAGE	AUX	1944	1958	6,873		STM TUR	9	1	809			NISMF	VA	N	N	N	Y
129	N5	AR5	AR8	JASON	AUX	1943	1995	9,140		STM TUR	11	1	831	5	2,031	NISMF	WA	N	N	M	-
130	N5	ARS5	ARS42	RECLAIMER	AUX	1945	1994	1,530		DIESEL ELEC	2	2	319	1	3,060	NISMF	HI	N	N	M	-
131	N5	AS31	AS32	HOLLAND	AUX		1996	10,500		DIESEL ELEC	15	1	700	12	875	Suisun Bay (RF)	CA	N	N	M	-

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
133	N5	AS36	AS37	DIXON	AUX	1970	1995	13,840		STM TUR	20	1	692	11	1,258		VA	N	N	M	Y
134	N5	ASR7	ASR9	FLORIKAN	AUX	1942	1991	1,780		DIESEL ELEC	3	1	593	1	3,560	NISMF	HI	N	N	M	Y
135	N5	ASR7	ASR13	KITTIWAKE	AUX	1945	1994	1,780		DIESEL ELEC	3	1	593	1	3,560		VA	N	M	M	-
136	N5	LPD1	LPD2	VANCOUVER	AMP	1962	1992	8,040		STM TUR	24	2	168	4	2,233	NISMF	HI	N	M	M	-
137	N5	LPD4	LPD5	OGDEN	AMP	1964	2003	9,700		STM TUR	24	2	202	4	2,694	ACTIVE		N	N	N	-
138	N5	LPD4	LPD6	DULUTH	AMP	1965	2005	9,700		STM TUR	24	2	202	4	2,694	ACTIVE		N	N	N	N
144	N5	APA128	AGM23	RANGE SENTINEL	AUX	1944	1999	6,873		STM TUR	9	1	809	4	1,809	NISMF	PA	N	N	N	-
146	N5	AGS26	AGS34	WYMAN	AUX	1969	1999	1,935		DIESEL ELEC	4	1	538	1	1,935	NISMF	HI	N	N	M	-
147	N5	ARS5	ARS6	ESCAPE	AUX	1942	1995	1,530		DIESEL ELEC	2	2	319	1	3,060	NISMF	PA	N	N	M	Y
157	N5	AE21	AE23	NITRO	AUX	1958	1995	7,470		STM TUR	16	1	467			NISMF	PA	N	N	N	Y
167	N5	AO143	AO145	HASSAYAMPA	AUX	1955	1994	11,944		STM TUR	28	2	427	2	7,465	Suisun Bay (RF)	CA	N	M	M	-
168	N5	AO143	AO146	KAWISHIWI	AUX	1955	1994	11,600		STM TUR	28	2	414			Suisun Bay (RF)	CA	N	M	M	-
169	N5	AO143	AO144	MISSISSENEWA	AUX	1954	1994	11,600		STM TUR	28	2	414			James River (RF)	VA	N	M	M	Y
170	N5	AO143	AO143	NEOSHO	AUX	1953	1994	11,600		STM TUR	28	2	414			James River (RF)	VA	N	M	M	Y
171	N5	AO143	AO148	PONCHATOULA	AUX	1955		11,600		STM TUR	38	2	305			Suisun Bay (RF)	CA	N	M	M	-
172	N5	AO49	AO155	ROANOKE	AUX	1974	1995	5,370		STM TUR ELEC	7		746			Suisun Bay (RF)	CA	N	M	M	-
175	N5	AOR5	AOR5	WABASH (EX AOR 5)	AUX	1970	1997	12,500		STM TUR	32		391			Suisun Bay (RF)	CA	N	M	M	-
176	N5	AOR1	AOR1	WICHITA	AUX	1968	1993	12,500		STM TUR	32		391			Suisun Bay (RF)	CA	N	M	M	-
177	N5	AR5	AR5	VULCAN	AUX	1941	1992	9,140		STM TUR	11		831			James River (RF)	VA	N	M	M	Y
179	N5	ARS5	ARS33	CLAMP	AUX	1943	1963	1,530		DIESEL ELEC	2		638			Suisun Bay (RF)	CA	N	M	M	-
180	N5	ARS5	ARS41	OPPORTUNE	AUX	1945	1993	1,530		DIESEL ELEC	2		638			James River (RF)	VA	N	M	M	Y
181	N5	AS11	AS12	SPERRY	AUX	1941	1982	10,100		DIESEL ELEC	11		902			Suisun Bay (RF)	CA	N	M	M	-
182	N5	AS11	AS17	NEREUS	AUX	1945	1993	10,100		DIESEL ELEC	11		902			Suisun Bay (RF)	CA	N	M	M	-
183	N5	AS11	AS18	ORION	AUX	1943	1993	10,100		DIESEL ELEC	11		902			James River (RF)	VA	N	M	M	Y
184	N5	AS11	AS19	PROTEUS	AUX	1942		10,100		DIESEL ELEC	11		902			Suisun Bay (RF)	CA	N	M	M	-
185	N5	AS33	AS34	CANOPUS	AUX	1965	1995	13,840		STM TUR	20	1	692	11	1,258	James River (RF)	VA	N	M	M	-
186	N5	AS11	AS16	HOWARD W. GILMORE	AUX	1943	1980	10,100		DIESEL ELECT	12		856			James River (RF)	VA	N	M	M	Y
187	N5	AS31	AS31	HUNLEY	AUX	1962	1995	10,500		DIESEL ELECT	15		700			James River (RF)	VA	N	M	M	Y
188	N5	ASR21	ASR22	ORTOLON	AUX	1969	1995	2,725		DIESEL	6		454			James River (RF)	VA	N	M	M	-
189	N5	ASR7	ASR14	PETREL	AUX	1946	1991	1,780		DIESEL ELEC	3		593			James River (RF)	VA	N	M	M	Y
191	N5	ASR7	ASR15	SUNBIRD	AUX	1945	1993	1,780		DIESEL ELEC	3		593			James River (RF)	VA	N	M	M	-
199	N5	CG26	CG30	HORNE	SCA	1964	1994	5,340		STM TUR	85	2	31	7	785	Suisun Bay (RF)	CA	N	M	N	-
244	N5	LSD1	LSD20	DONNER	AMP	1945	1976	4,790		STM TUR	7		684			James River (RF)	VA	N	M	M	-
245	N5	LSD28	LSD35	MONTICELLO	AMP	1956	1992	6,880		STM TUR	24		287			Suisun Bay (RF)	CA	N	M	N	-
246	N5	LSD28	LSD32	SPIEGEL GROVE	AMP	1956	1989	6,880		STM TUR	24		287			James River (RF)	VA	N	M	M	-
247	N5	LSD28	LSD31	POINT DEFIANCE	AMP	1954		6,880		STM TUR	24		287			Suisun Bay (RF)	CA	N	M	M	-
248	N5	LSD28	LSD28	THOMASTON	AMP	1954	1984	6,880		STM TUR	24		287			Suisun Bay (RF)	CA	N	M	N	-
250	N5	LST1156	LST1162	WAHKIAKUM COUNTY	AMP	1953	1973	2,590		DIESEL	6	2	432			Suisun Bay (RF)	CA	N	M	M	-
251	N5	LST1171	LST1178	WOOD COUNTY	AMP	1958	1989	4,164		DIESEL	14	2	289			James River (RF)	VA	N	M	M	-
252	N5	LST1156	LST1158	TIOGA COUNTY	AMP	1953	1992	2,590		DIESEL	8	2	324			Suisun Bay (RF)	CA	N	M	N	-
270	N5	ARS5	ARS38	BOLSTER	AUX	1944	1994	1,530		DIESEL ELEC	2		638			Suisun Bay (RF)	CA	N	M	M	-
271	N5	ARS5	ARS8	PRESERVER	AUX	1943	1994	1,530		DIESEL ELEC	2		638			James River (RF)	VA	N	M	M	Y
340	N5	Barracks CRF	APL57	APL 57	Barracks	1945		2,000	e							James River (RF)	VA	N	M	M	-
346	N5	Navy Oiler	AO98	CALOOSAHATCHEE	T3-S2-A1J	1945		9,917		STM TUR	13.5		735			James River (RF)	VA	N	M	M	Y
347	N5	Navy Oiler	AO99	CANISTEO	T3-S2-A7	1945		9,917		STM TUR	13.5		735			James River (RF)	VA	N	M	M	Y

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
349	N5	EX German Salvage Barg	YHLC2	CRANDALL	GERMAN	1943		1000	e							James River (RF)	VA	N	M	M	-
350	N5	EX German Salvage Barg	YHLC1	CRILLEY	GERMAN	1943		1000	e							James River (RF)	VA	N	M	M	-
351	N5	EX TUSKEGEE VICTORY	AGS22	DUTTON	VC2-S-AP3	1945		7,190		STM TUR	9.4	1	765	1	11,983	Beaumont (RF)	TX	N	M	M	-
357	N5	EX FURMAN VICTORY	AK281	FURMAN	VC2-	1945		6,700		STM TUR	9.4	1	713	1	11,167	Beaumont (RF)	TX	N	M	M	-
358	N5	AP120	AP122	GEN ALEXANDER M PATCH	P2-S	1944		12,603		STM TUR ELEC	20.5	2	615	2	5,251	James River (RF)	VA	N	M	M	-
359	N5	AP120	AP124	GEN EDWIN D PATRICK	P2-S	1945		12,603		STM TUR ELEC	20.5	2	615	2	5,251	Suisun Bay (RF)	CA	N	M	M	-
360	N5	EX AP145	AGM10	GEN HOYT S VANDENBERG	M C4-S	1944		13,051		STM TUR	9.9	1	1,318	1	10,876	James River (RF)	VA	N	M	M	-
361	N5	AP110	AP110	GEN JOHN POPE	P2-S	1943		12,603		STM TUR	18.7	1	674	2	7,877	Suisun Bay (RF)	CA	N	M	M	-
362	N5	AP120	AP125	GEN NELSON M WALKER	P2-S	1945		12,603		STM TUR ELEC	20.5	2	615	2	5,251	James River (RF)	VA	N	M	M	-
363	N5	AP120	AP127	GEN WILLIAM O. DARBY	P2-SE2-R1	1945		12,603		STM TUR ELEC	20.5	2	615	2	5,251	James River (RF)	VA	N	M	M	N
371	N5	Tanker	AO105	MISPILLION	T3S2	1945		14,763		STM TUR	15.2	2	971	6	2,461	Suisun Bay (RF)	CA	N	M	M	-
372	N5	Tanker	AO134	MISSION SANTA YNEZ	T2-S	1944		5,730		STM TUR ELEC	10.0	1	573	1	7,163	Suisun Bay (RF)	CA	N	M	M	-
373	N5	AK270	AK272	MIZAR	OR C1ME	1958		1,850		STM TUR	28.0	2	66			James River (RF)	VA	N	M	M	-
379	N5	Tanker	AO105	PAWCATUCK	T3S2	1946		11,000		STM TUR	13.5	2	815			James River (RF)	VA	N	M	M	Y
381	N5	ex AKD1, POINT BARROW	AGDS	POINT LOMA	AKD-1	1958		5,562		STM TUR	12.0	2	464			Suisun Bay (RF)	CA	N	M	M	-
382	N5	AGR1	AGR11	PROTECTOR	R Z-EC	1945		3,600		VTE	2.5	1	1,440			James River (RF)	VA	N	M	M	-
386	N5	AF58	AF58	RIGEL	R3S4	1955		7,950		STM TUR	16.0	1	497	2	3,457	James River (RF)	VA	N	M	M	Y
390	N5	Tanker	AO75	SAUGATUCK	T2-S	1942		5,370		STM TUR ELEC	7.4	1	726	1	6,713	James River (RF)	VA	N	M	M	Y
393	N5	Tanker	AO62	TALUGA	T3-S	1944		7,256		STM TUR	13.5	2	537			Suisun Bay (RF)	CA	N	M	M	-
395	N5	Tanker	AO147	TRUCKEE	T2-SE-A2	1955	1955	11,600		STM TUR	28	2	414			James River (RF)	VA	N	M	M	Y
396	N5	Military Auxiliary	LKA	TULARE	C4-S	1956		9,050		STM TUR	22.0	1	411			Suisun Bay (RF)	CA	N	M	M	-
398	N5		TAG194	VANGUARD	T2-SE-A2	1943	1966	5,730		STM TUR	10		573			James River (RF)	VA	N	M	M	-
406	N5	Tanker	AOG81	ALATNA	T1-MET-24a	1955		3,459		DIESEL	4.4		786			Tsuneishi, JAPAN		N	M	M	-
410	N5	Tanker	AO	AMERICAN EXPLORER	T5-S	1959		8,402		STM TUR	22.0	1	382	2	5,601	Beaumont (RF)	TX	N	M	M	-
429	N5	Dry Cargo		CAPE COD	C3-S-37c	1963		5,876		STM TUR	11.0	1	534	1	4,897	James River (RF)	VA	N	M	M	-
435	N5	AOG81	AOG82	CHATTAHOOCHEE	T1-MET-24a	1957		3,459		DIESEL ELEC	3.4		1,017			Tsuneishi, JAPAN		N	M	M	-
448	N5	AGS38	AGS38	H H HESS	C4SA	1965		9,936		STM TUR	19.3	1	515	2	4,516	Suisun Bay (RF)	CA	N	M	M	-
449	N5	AGS29	AGS32	HARKNESS	FORN	1971		2,640		DIESEL	3.1	1	852	1	2,200	James River (RF)	VA	N	M	M	-
458	N5	Ballistic Missile Supply	AK282	MARSHFIELD	VC2-	1944		6,700		STM TUR	9.4	1	713	1	11,167	James River (RF)	VA	N	M	M	-
460	N5	Tanker	AO	MAUMEE	T5-S	1956		7,882		STM TUR	20.5	1	384	1	7,882	Beaumont (RF)	TX	N	M	M	-
461	N5	EX AK278 SEA LIFT		METEOR	C4-ST-67	1967		16,940		STM TUR	19.4		873	2	11,293	Alameda, CA	CA	N	M	M	-
462	N5	AK270	AK271	MIRFAK	C C1-M	1957		1,850		STM TUR	28.0	2	66			James River (RF)	VA	N	M	M	-
463	N5	Tanker		MISSION BUENAVENTURA	Stm/38K	1968		8,005		STM TUR	15.0		534	2	4,003	Beaumont (RF)	TX	N	M	M	-
464	N5	Tanker		MISSION CAPISTRANO	Dsl/37K	1971		8,611		DIESEL	15.0		574	1	8,611	Beaumont (RF)	TX	N	M	M	-
467	N5	Tanker	AOG78	NODAWAY	T1-M-BT2	1945		2,060		DIESEL	1.4		1,471	1	4,120	Tsuneishi, JAPAN		N	M	M	-
483	N5	Tanker	AO151	SHOSHONE	T5-S	1957		7,814		STM TUR	20.5	1	381	1	7,814	Suisun Bay (RF)	CA	N	M	M	-
485	N5	AK284	AK285	SOUTHERN CROSS	C3-S	1962		5,846		STM TUR	12.1	1	483	1	4,872	James River (RF)	VA	N	M	M	-
492	N5	Experimental Nav Ship	EAG153	COMPASS ISLAND		1956	1981	9,050		STM TUR	19.3		469			James River (RF)	VA	N	M	M	
493	N5	LPD5	LPD9	DENVER	AMP	1965	2005	9,700		STM TUR	24	2	202	4	2,694	ACTIVE		N	N	N	
494	N5	AOR1	AOR2	MILWAUKEE	AUX	1969		12,500		STM TUR	32	2	195	9	1,389	James River (RF)	VA	N	M	M	
495	N5	LPD6	LPD12	SHREVEPORT	AMP	1966	2004	9,700		STM TUR	24	2	202	4	2,694	ACTIVE		N	N	N	
496	N5	Tanker	AO109	WACCAMAW	T3S3	1946		14,763		STM TUR	15.2	2	971	7	2,109	James River (RF)	VA	N	M	M	
140	N6	LPH2	LPH3	OKINAWA	AMP	1961	1992	10,722		STM TUR	22	1	487	7	1,650		CA	N	M	M	Y
148	N6	ATF67	ATF91	SENECA	AUX	1943	1985	1,235		DIESEL ELEC	3	2	206	1	882	James River (RF)	VA	N	M	N	-
151	N6	CG16	CG24	REEVES	SCA	1962	1993	5,670		STM TUR	85	2	33	7	834	NISMF	HI	N	N	N	Y

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
152	N6	DD931	DD931	FORREST SHERMAN	SCA	1955	1982	2,850		STM TUR	70	2	20			NISMF	PA	N	N	N	Y
153	N6	DD931	DD932	JOHN PAUL JONES	SCA	1955	1986	2,850		STM TUR	70	2	20			NISMF	WA	N	N	N	N
205	N6	DD931	DD942	BIGELOW	SCA	1957	1990	2,850		STM TUR	70	2	20			NISMF	PA	N	N	N	-
213	N6	DDG2	DDG7	HENRY B WILSON	SCA	1959	1990	3,640		STM TUR	70	2	26	2	1,655	Suisun Bay (RF)	CA	N	M	N	-
214	N6	DDG2	DDG8	LYNDE MCCORMICK	SCA	1959	1992	3,640		STM TUR	70	2	26	2	1,655	Suisun Bay (RF)	CA	N	M	N	-
265	N6	SS580	SS580	BARBEL	SUB	1958	1989	2,155		DIESEL ELEC	5	1	449				CA	N	N	N	-
268	N6	ATF67	ATF149	ATAKAPA	AUX	1944	1992	1,235		DIESEL ELEC	3	1	412			James River (RF)	VA	N	M	N	Y
276	N6	ATA121	ATA143	KEYWADIN	OTH	1945	1980	610		DIESEL ELEC	2	1	407	1	508		VA	N	N	N	-
497	N6	Tanker	AO51	ASHTABULA	T3-S	1943	1983	7,256		STM TUR	13.5	2	537			Suisun Bay (RF)	CA	N	M	M	
5	N8	DD963	DD964	PAUL F FOSTER	SCA	1974	2005	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	N
7	N8	DD963	DD968	ARTHUR W RADFORD	SCA	1975	2005	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	N
8	N8	DD963	DD970	CARON	SCA	1975	2002	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	N
9	N8	DD963	DD971	DAVID R RAY	SCA	1975	2002	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	N
11	N8	DD963	DD975	O'BRIEN	SCA	1976	2001	5,830		GAS TUR	80	2	36	6	972	ACTIVE		N	N	N	-
141	N8	LPH2	LPH7	GUADALCANAL	AMP	1963	1994	10,722		STM TUR	22	1	487	7	1,650	NISMF	PA	N	M	N	Y
142	N8	LPH2	LPH9	GUAM	AMP	1964	1998	10,722		STM TUR	22	1	487	7	1,650		VA	N	N	N	Y
158	N8	DD963	DD974	COMTE DE GRASSE	SCA	1976	1998	5,830		GAS TUR	80	2	36	6	972	NISMF	PA	N	N	N	N
159	N8	DD963	DD986	HARRY W HILL	SCA	1978	1998	5,830		GAS TUR	80	2	36	6	972	NISMF	HI	N	N	N	-
160	N8	FFG7	FFG34	AUBREY FITCH	SCA	1981	1997	2,750		GAS TUR	40	1	69	3	917	NISMF	PA	N	N	N	-
161	N8	AE21	AE22	MAUNA KEA	AUX	1957		7,470		STM TUR	16		467			Suisun Bay (RF)	CA	N	M	M	-
163	N8	AGOR3	AGOR7	LYNCH	AUX	1965		1,200		DIESEL ELEC	10	1	120			James River (RF)	VA	N	M	M	Y
165	N8	AGOR3	AGOR3	ROBERT D. CONRAD	AUX	1962	1989	1,200		DIESEL ELEC	10		120			James River (RF)	VA	N	M	N	Y
173	N8	AOG10	AOG10	NEMASKET	AUX	1942	1979	1,850		DIESEL ELEC	3		597			Suisun Bay (RF)	CA	N	M	M	-
174	N8	AOG4	AOG4	WABASH (EX AOG 4)	AUX	1943	1979	1,850		DIESEL ELEC	3		597			Suisun Bay (RF)	CA	N	M	M	-
192	N8	CG16	CG16	LEAHY	SCA	1961	1993	5,670		STM TUR	85	2	67	7	834	Suisun Bay (RF)	CA	N	M	N	Y
193	N8	CG16	CG17	HARRY E YARNELL	SCA	1961	1993	5,670		STM TUR	85	2	33	7	834	NISMF	PA	N	N	N	Y
194	N8	CG16	CG21	GRIDLEY	SCA	1961	1994	5,670		STM TUR	85	2	33	7	834	Suisun Bay (RF)	CA	N	M	N	Y
195	N8	CG16	CG22	ENGLAND	SCA	1962	1994	5,670		STM TUR	85	2	33	7	834	Suisun Bay (RF)	CA	N	M	N	Y
196	N8	CG16	CG23	HALSEY	SCA	1962	1994	5,670		STM TUR	85	2	33	7	834	Suisun Bay (RF)	CA	N	M	N	N
197	N8	CG26	CG28	WAINWRIGHT	SCA	1964	1993	5,340		STM TUR	85	2	31	7	785	NISMF	PA	N	N	N	Y
198	N8	CG26	CG29	JOUETT	SCA	1964	1994	5,340		STM TUR	85	2	31	7	785	Suisun Bay (RF)	CA	N	M	N	-
200	N8	CG26	CG32	WILLIAM H STANDLEY	SCA	1964	1994	5,340		STM TUR	85	2	31	7	785	Suisun Bay (RF)	CA	N	M	N	-
201	N8	CG26	CG33	FOX	SCA	1964	1994	5,340		STM TUR	85	2	31	7	785	Suisun Bay (RF)	CA	N	M	N	-
202	N8	CG26	CG34	BIDDLE	SCA	1965	1993	5,340		STM TUR	85	2	31	7	785	NISMF	PA	N	N	N	Y
203	N8	CV63	CV66	AMERICA	CV	1964	1996	56,300		STM TUR	280	4	50	15	3,753	NISMF	PA	N	N	N	Y
204	N8	CV9	CV34	ORISKANY	CV	1945	1989	33,250		STM TUR	150	4	55			Beaumont (RF)	TX	N	M	N	-
206	N8	DD963	DD976	MERRILL	SCA	1976	1998	5,830		GAS TUR	80	2	36	6	972	NISMF	HI	N	N	N	-
207	N8	DD963	DD983	JOHN RODGERS	SCA	1978	1998	5,830		GAS TUR	80	2	36	6	972	NISMF	PA	N	N	N	-
208	N8	DD963	DD984	LEFTWICH	SCA	1978	1998	5,830		GAS TUR	80	2	36	6	972			N	N	N	-
209	N8	DD963	DD990	INGERSOLL	SCA	1979	1998	5,830		GAS TUR	80	2	36	6	972	NISMF	HI	N	N	N	-
210	N8	DDG2	DDG4	LAWRENCE	SCA	1960	1990	3,640		STM TUR	70	2	26	2	1,655	NISMF	PA	N	N	N	Y
211	N8	DDG2	DDG5	CLAUDE V RICKETTS	SCA	1960	1989	3,640		STM TUR	70	2	26	2	1,655	NISMF	PA	N	N	N	Y
212	N8	DDG2	DDG6	BARNEY	SCA	1960	1990	3,640		STM TUR	70	2	26	2	1,655	NISMF	PA	N	N	N	Y
215	N8	DDG2	DDG9	TOWERS	SCA	1959	1990	3,640		STM TUR	70	2	26	2	1,655	Suisun Bay (RF)	CA	N	M	N	Y
216	N8	DDG2	DDG10	SAMPSON	SCA	1960	1991	3,640		STM TUR	70	2	26	2	1,655	NISMF	PA	N	N	N	Y

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
217	N8	DDG2	DDG11	SELLERS	SCA	1960	1989	3,640		STM TUR	70	2	26	2	1,655	NISMF	PA	N	N	N	Y
218	N8	DDG2	DDG21	COCHRANE	SCA	1962	1990	3,640		STM TUR	70	2	26	2	1,655	NISMF	HI	N	N	N	Y
219	N8	DDG2	DDG22	BENJAMIN STODDERT	SCA	1963	1991	3,640		STM TUR	70	2	26	2	1,655	NISMF	HI	N	N	N	Y
220	N8	DLG6	DLG37	FARRAGUT	SCA	1958	1989	4,150		STM TUR	85	2	24	4	1,038	NISMF	PA	N	N	N	Y
221	N8	DLG6	DLG38	LUCE	SCA	1958	1991	4,150		STM TUR	85	2	24	4	1,038	NISMF	PA	N	N	N	Y
222	N8	DLG6	DLG39	MACDONOUGH	SCA	1961	1992	4,150		STM TUR	85	2	24	4	1,038	NISMF	PA	N	N	N	Y
223	N8	DLG6	DLG40	COONTZ	SCA	1960	1989	4,150		STM TUR	85	2	24	4	1,038	NISMF	PA	N	N	N	Y
224	N8	DLG6	DLG42	MAHAN	SCA	1960	1993	4,150		STM TUR	85	2	24	4	1,038	NISMF	PA	N	N	N	Y
225	N8	DLG6	DLG43	DAHLGREN	SCA	1961	1992	4,150		STM TUR	85	2	24	4	1,038	NISMF	PA	N	N	N	Y
226	N8	DLG6	DLG46	PREBLE	SCA	1960	1991	4,150		STM TUR	80	2	26	4	1,038	NISMF	PA	N	N	N	Y
227	N8	DE1040	DE1043	EDWARD MCDONNELL	SCA	1964	1988	2,620		STM TUR	35	1	75	2	1,310	NISMF	PA	N	N	N	Y
229	N8	DE1052	DE1053	ROARK	SCA	1967	1991	3,011		STM TUR	35	1	86	3	1,004	NISMF	WA	N	N	N	-
231	N8	DE1052	DE1055	HEPBURN	SCA	1967	1991	3,011		STM TUR	35	1	86	3	1,004	NISMF	WA	N	N	N	-
232	N8	DE1052	DE1057	RATHBURNE	SCA	1969	1991	3,011		STM TUR	35	1	86	3	1,004	NISMF	HI	N	N	N	Y
233	N8	DE1052	DE1058	MEYERKORD	SCA	1967	1991	3,011		STM TUR	35	1	86	3	1,004	Suisun Bay (RF)	CA	N	M	N	-
234	N8	DE1052	DE1060	LANG	SCA	1968	1991	3,011		STM TUR	35	1	86	3	1,004	Suisun Bay (RF)	CA	N	M	N	-
237	N8	DE1052	DE1067	FRANCIS HAMMOND	SCA	1968	1992	3,011		STM TUR	35	1	86	3	1,004	NISMF	WA	N	N	N	-
239	N8	DE1052	DE1070	DOWNES	SCA	1969	1992	3,011		STM TUR	35	1	86	3	1,004	NISMF	WA	N	N	N	-
241	N8	DE1052	DE1074	HAROLD E HOLT	SCA	1969	1995	3,011		STM TUR	35	1	86	3	1,004	NISMF	HI	N	N	N	-
243	N8	FFG7	FFG31	STARK	SCA	1980	1999	2,750		GAS TUR	40	1	69	3	917			N	N	N	-
253	N8	MHC43	MHC43	BITTERN	MINE	1957	1972	300		DIESEL	1	2	125			NISMF	PA	N	N	N	Y
255	N8	MSO421	MSO433	ENGAGE	MINE	1953	1991	684		DIESEL	2	2	149			NISMF	PA	N	N	N	Y
259	N8	MSO421	MSO440	EXPLOIT	MINE	1953	1993	684		DIESEL	2	2	149				VA	N	N	N	Y
260	N8	MSO421	MSO441	EXULTANT	MINE	1953	1993	684		DIESEL	2	2	149				VA	N	N	N	Y
261	N8	MSO421	MSO446	FORTIFY	MINE	1953	1992	684		DIESEL	2	2	149				VA	N	N	N	Y
262	N8	MSO421	MSO449	IMPERVIOUS	MINE	1952	1991	684		DIESEL	2	2	149			NISMF	PA	N	N	N	Y
263	N8	MSO421	MSO511	AFFRAY	MINE	1956	1992	684		DIESEL	2	2	149				VA	N	N	N	Y
264	N8	SSR572	SS572	SAILFISH	SUB	1955	1978	2,485		DIESEL ELEC	6	2	207			NISMF	WA	N	N	N	-
269	N8	YTB752	YTB785	WINNEMUCCA	OTH	1966		300		DIESEL						Suisun Bay (RF)	CA	N	M	N	-
272	N8			YC 1471	OTH			175		NONE						Suisun Bay (RF)	CA	N	M	N	-
273	N8	YFNB5	YFNB5	YFNB 5	OTH	1945		831		NONE						Suisun Bay (RF)	CA	N	M	N	-
498	N8	DD966	DD989	DEYO	SCA	1979	2005	5,833		GAS TUR	80	2	36	9	648	ACTIVE		N	N	N	
499	N8	DD965	DD967	ELLIOTT	SCA	1977	2005	5,832		GAS TUR	80	2	36	8	729	ACTIVE		N	N	N	
500	N8	DD964	DD965	KINKADE	SCA	1976	2005	5,831		GAS TUR	80	2	36	7	833	ACTIVE		N	N	N	
501	N8	Barge	YC824		OTH			175		NONE						Suisun Bay (RF)	CA	N	M	N	
502	N8	Barge	YC826		OTH			175		NONE						Suisun Bay (RF)	CA	N	M	N	
190	N9	ASR21	ASR21	PIGEON	AUX	1969	1992	2,725		DIESEL	6		454			Suisun Bay (RF)	CA	N	M	M	-
274	N9	TATF166	TATF166	POWHATTAN	AUX	1978	1998	2,200		DIESEL	5	2	244	1	1,833	DON JON		N	O	N	-
275	N9	AG193	AG193	GLOMAR EXPLORER	OTH	1972		63,300		DIESEL ELEC	13	2	2,435			HOUSTON	TX	O	O	N	-
277	N9	DD931	DD936	DECATUR	SCA	1955	1988	2,850		STM TUR	70	2	20			Port Hueneme	CA	N	N	N	-
278	N9	LSD1	LSD15	SHADWELL	AMP	1944	1970	4,790		STM TUR	7	2	342			Mobile	AL	N	N	N	-
279	N9	PG84	PG85	GALLOP	OTH	1965	1984	225		CODAG	15	2	8			Panama City	FL	N	N	N	-
280	N9	PG84	PG90	CANON	OTH	1967	1984	225		CODAG	15	2	8			Panama City	FL	N	N	N	-
281	N9	PG84	PG94	CHEHALIS	OTH	1968	1973	225		CODAG	15	2	8			Panama City	FL	N	N	N	-
282	N9	PG84	PG98	GRAND RAPIDS	OTH	1970	1977	225		CODAG	15	2	8			Panama City	FL	N	N	N	-

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
283	N9	PG84	PG100	DOUGLAS	OTH	1970	1977	225		CODAG	15	2	8			Panama City	FL	N	N	N	-
284	N9	SS563	SS566	TROUT	SUB	1951	1978	1,560		DIESEL ELEC	4	2	195			Key West	FL	N	N	N	Y
285	N9	SS572	SS573	SALMON	SUB	1956	1977	2,485		DIESEL ELEC	6	2	207			New London	CT	N	N	N	-
503	N9	AGOS1	AGOS10	INVINCIBLE	AUX			2,285		DIESEL	3	2	357	3	762	MSC		N	O	N	
504	N9	ATA121	ATA203	NAVIGATOR	OTH	1945	1962	610		DIESEL ELEC	2	1	407	2	277	MDSU ONE					
505	N9	LPH2	LPH10	TRIPOLI	AMP	1966	1995	10,722		STM TUR	22	1	487	8	1,430	Loan to Army					
286	N10	SS212	AGSS244	CAVALLA	SUB	1943		1,526		DIESEL ELEC	5	2	141			Galveston	TX	N	O	N	-
287	N10	SS212	SS228	DRUM	SUB	1941		1,526		DIESEL ELEC	5	2	141			Mobile	AL	N	O	N	-
288	N10	SS212	SS236	SILVERSIDES	SUB	1941		1,526		DIESEL ELEC	5	2	141			Muskegon	MI	N	O	N	-
289	N10	SS212	SS245	COBIA	SUB	1943		1,526		DIESEL ELEC	5	2	141			Manitowoc	WI	N	O	N	-
290	N10	SS212	SS246	CROAKER	SUB	1943		1,526		DIESEL ELEC	5	2	141			Buffalo	NY	N	O	N	-
291	N10	SS285	SS297	LING	SUB	1942		1,525		DIESEL ELEC	5	2	141			Hackensack	NJ	N	O	N	-
292	N10	SS285	SS310	BATFISH	SUB	1943		1,525		DIESEL ELEC	5	2	141			Muskogee	OK	N	O	N	-
293	N10	SS417	SS423	TORSK	SUB	1944		1,570		DIESEL ELEC	5	2	145			Baltimore	MD	N	O	N	-
294	N10	SS417	SS481	REQUIN	SUB	1945		1,570		DIESEL ELEC	5	2	145			Pittsburge	PA	N	O	N	-
295	N10	AGSS569	AGSS569	ALBACORE	SUB	1953	1980	1,517		DIESEL ELEC	2	1	1,011			Portsmouth	NH	N	O	N	-
296	N10	BB35	BB35	TEXAS	BB	1914	1948	24,863		STM RECP	25	2	497			La Porte	TX	N	O	N	-
297	N10	BB55	BB55	NORTH CAROLINA	BB	1941	1960	35,040		STM TUR	121	4	72			Wilmington	NC	N	O	N	-
298	N10	BB59	BB59	MASSACHUSETTES	BB	1942	1962	34,575		STM TUR	130	4	66			Fall River	MA	N	O	N	-
299	N10	BB60	BB60	ALABAMA	BB	1942	1962	34,575		STM TUR	130	4	66			Mobile	AL	N	O	N	-
300	N10	BB61	BB61	IOWA	BB	1942	1991	48,425		STM TUR	212	4	57	11	4,612	NISMF	PA	N	N	N	Y
301	N10	BB61	BB62	NEW JERSEY	BB	1942	1991	48,425		STM TUR	212	4	57	11	4,612		HI	N	N	N	-
302	N10	BB61	BB63	MISSOURI	BB	1942	1995	48,425		STM TUR	212	4	57	11	4,612	Honolulu	HI	N	O	N	Y
303	N10	BB61	BB64	WISCONSIN	BB	1943	1991	48,425		STM TUR	212	4	57	11	4,612		VA	N	N	N	Y
304	N10	Z	C6	OLYMPIA	OTH	1896		5,695		STM RECP	17	2	168			Philadelphia	PA	N	O	N	-
305	N10	SSN571	SSN571	NAUTILUS	SUB	1954	1980	3,530		STM TUR	15	2	118			New London	CT	N	N	N	-
306	N10	CA134	CA139	SALEM	SCA	1947	1991	17,000		STM TUR	120	4	35	8	2,208	Quincy	MA	N	O	N	Y
307	N10	CLG3	CLG4	LITTLE ROCK	SCA	1960	1977	13,600		STM TUR	120	4	28			Buffalo	NY	N	O	N	-
308	N10	CV9	CV12	HORNET	CV	1943	1989	33,250		STM TUR	150	4	55	6	6,045	Oakland	CA	N	O	N	Y
309	N10	CV9	CV16	LEXINGTON	CV	1942	1991	33,250		STM TUR	150	4	55	6	6,045	Corpus Christie	TX	N	O	N	-
310	N10	CV9	CV10	YORKTOWN	CV	1943	1973	33,250		STM TUR	150	4	55	6	6,045	Mt. Pleasant	SC	N	O	N	-
311	N10	CV9	CV11	INTREPID	CV	1943	1982	33,250		STM TUR	150	4	55	6	6,045	New York City	NY	N	O	N	-
312	N10	DD445	DD537	THE SULLIVANS	SC	1943	1974	2,050		STM TUR	60	2	17	1	4,100	Buffalo	NY	N	O	N	-
313	N10	DD445	DD661	KIDD	SC	1943	1974	2,050		STM TUR	60	2	17	1	4,100	Baton Rouge	LA	N	O	N	-
314	N10	DD692	DD724	LAFFEY	SC	1943	1975	2,290		STM TUR	60	2	19	1	2,544	Mt. Pleasant	SC	N	O	N	-
315	N10	DD445	DD793	CASSIN YOUNG	SC	1943	1974	2,050		STM TUR	60	2	17	1	4,100	Charleston	SC	N	O	N	-
316	N10	DD710	DD850	JOSEPH P. KENNEDY	SC	1945	1974	2,425		STM TUR	60	2	20	1	2,694	Fall River	MA	N	O	N	-
317	N10	DD931	DD933	BARRY	SCA	1955	1983	2,850		STM TUR	70	2	20			Washington	DC	N	N	N	N
318	N10	DD931	DD946	EDSON	SCA	1958	1988	2,850		STM TUR	70	2	20			New York City	NY	N	O	N	-
319	N10	DD931	DD951	TURNER JOY	SCA	1958	1990	2,850		STM TUR	70	2	20			Bremerton	WA	N	O	N	-
320	N10	DE129	DE238	STEWART	SC	1942	1992	1,200		DIESEL	6	2	100	1	2,000	Galveston	TX	N	O	N	-
321	N10	Sailing Vessel	IX20	CONSTELLATION	OTH			0		SAIL	0	0		0		Baltimore	MD	N	O	N	-
322	N10	Sailing Vessel	IX21	CONSTITUTION	OTH			0		SAIL	0	0		0		Boston	MA	N	O	N	-
323	N10	SS285	IXSS298	LIONFISH	SUB	1942		1,525		DIESEL ELEC	5	2	141			Fall River	MA	N	O	N	-
324	N10	MSB5	MSB5		MINE											Fort Worth	TX	N	O	N	-

Table A.1 (continued)

NUMBER	CATEGORY	CLASS/TYPE	HULL	NAME	SHIP TYPE	YR BUILT	YR STRICKEN OR TO INACT	LT LSW	ESTIMATED	PROP SYS	KSHP	#SHAFTS	T/KSHP	MW ELECT PWR GEN	T/MW	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER	PCBs
325	N10	PTF17	PTF17	NASTY CLASS	OTH			70	e	DIESEL	6	2	6			Buffalo	NY	N	O	N	-
326	N10	SS285	SS319	BECUNA	SUB	1944	1973	1,525		DIESEL ELEC	5	2	141			Philadelphia	PA	N	O	N	-
327	N10	SS285	SS383	PAMPANITO	SUB	1943		1,525		DIESEL ELEC	5	2	141			San Francisco	CA	N	O	N	-
328	N10	SS580	SS581	BLUEBACK	SUB	1958	1990	2,155		DIESEL ELEC	5	1	449			Portland	OR	N	O	N	-
329	N10	SS285	SS287	BOWFIN	SUB	1942		1,525		DIESEL ELEC	5	2	141			Honolulu	HI	N	O	N	-
330	N10	SS285	SS343	CLAMAGORE	SUB	1945	1975	1,525		DIESEL ELEC	5	2	141			Mt. Pleasant	SC	N	O	N	-
331	N10	SS212	SS224	COD	SUB	1943		1,526		DIESEL ELEC	5	2	141					N	O	N	-
332	N10	SST2	SST2	MARLIN	SUB					DIESEL ELEC						Omaha	NB	N	O	N	-
333	N10	U-BOAT	0505	U-BOAT	SUB											Chicago	IL	O	O	N	-
488	N10	SS577	SSG577	GROWLER	SUB	1957		2,540		DIESEL ELEC	6	2	212			New York City	NY	N	O	N	-
489	N10	YP654	YP671		OTH	1958		60		DIESEL	1	2	50	20	3	Chicago	IL	N	O	N	-
490	N10	YP654	YP673		OTH	1958		60		DIESEL	1	2	50	20	3	Southfield	MI	N	O	N	-

KEYS:

CATEGORIES:
N1 - NAVY MOBILIZATION AND OTHER RETENTION ASSETS
N2 - NAVY EXISTING FOREIGN MILITARY LEASES
N3 - NAVY POTENTIAL FUTURE FMS AND GRANTS
N4 - NAVY POTENTIAL DONATIONS OR COMMERCIAL LEASES
N5 - FORMER NAVY VESSELS, TITLE TRANSFERED TO MARAD FOR DISPOSITION
N6 - NAVY SINKEX CANDIDATES
N7 - NAVY HELD FOR SPARE PARTS
N8 - NAVY READY FOR DISPOSAL, HELD AT NISMFS OR MARAD
N9 - NAVY SPECIAL VESSELS
N10 - NAVY MUSEUM SHIPS
M1 - MARAD VESSELS ON MARAD INVENTORY - READY FOR DISPOSAL
M2 - MARAD VESSELS ON MARAD INVENTORY - MILITARY RETENTION, SPARE PARTS, ETC., SHIPS THAT ARE UNLIKELY TO BE RETAINED

ORIGINATOR, CUSTODIAN, TITLE HOLDER

	MARAD	Navy	Other Organization
Originator of the Vessel (Originator)	M	N	O
Current Custodian of the Vessel (Custodian)	M	N	O
Current Title Holder of the Vessel (Title Holder)	M	N	O

Table A.2
Ship Disposal Working Inventory

NUMBER	CATEGORY		CLASS/TYPE	HULL	NAME	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER
115	M1	1	T2-S/17K		ALBERT E. WATTS	Mobile, AL	AL	M	M	M
133	M1	2	Cable Layer (1980)	AR	ALBERT J MYER	James River (RF)	VA	M	M	M
147	M1	3	Dry Cargo	AK	AMERICAN RACER	Suisun Bay (RF)	CA	M	M	M
134	M1	4	Dry Cargo	AK	AMERICAN RANGER	James River (RF)	VA	M	M	M
131	M1	5	Military Auxiliary	AK	ARTHUR M HUDDELL	James River (RF)	VA	M	M	M
129	M1	6	Dry Cargo	AK	BARNARD VICTORY	Suisun Bay (RF)	CA	M	M	M
371	M1	7	Buoy Tender	WAGL388	BASSWOOD	Suisun Bay (RF)	CA	O	M	M
127	M1	8	Tanker	AOT	BEAUJOLAIS	Beaumont (RF)	TX	M	M	M
125	M1	9	Dry Cargo	AK	BUILDER	James River (RF)	VA	M	M	M
132	M1	10	Tanker	AOT	CONNECTICUT	Suisun Bay (RF)	CA	M	M	M
111	M1	11	Dry Cargo	AK	EARLHAM VICTORY	Suisun Bay (RF)	CA	M	M	M
130	M1	12	Dry Cargo	AK	EXPORT CHALLENGER	James River (RF)	VA	M	M	M
467	M1	13	Buoy Tender	WAGL212	FIR	Suisun Bay (RF)	CA	O	M	M
113	M1	14	Tanker	AOT	FLORENCE	Suisun Bay (RF)	CA	M	M	M
116	M1	15	Tanker	AOT	GETTYSBURG	Suisun Bay (RF)	CA	M	M	M
110	M1	16	Dry Cargo	AK	HANNIBAL VICTORY	Suisun Bay (RF)	CA	M	M	M
117	M1	17	Dry Cargo	AK	HATTIESBURG VICTORY	Beaumont (RF)	TX	M	M	M
379	M1	18	Buoy Tender	WAGL395	IRIS	Suisun Bay (RF)	CA	O	M	M
118	M1	19	Military Auxiliary	LP	LAUDERDALE	James River (RF)	VA	M	M	M
146	M1	20	Dry Cargo	AKV	MAINE	Beaumont (RF)	TX	M	M	M
114	M1	21	Military Auxiliary	AK	MARINE FIDDLER	James River (RF)	VA	M	M	M
337	M1	22	Tanker	AOT	MEACHAM	Beaumont (RF)	TX	M	M	M
338	M1	23	Dry Cargo	AK	MORMACDAWN	James River (RF)	VA	M	M	M
339	M1	24	Dry Cargo	AK	MORMACMOON	James River (RF)	VA	M	M	M
412	M1	25	Tanker	AOT	NAECO	Beaumont, TX	TX	M	M	M
341	M1	26	Cable Layer (1978)	AR	NEPTUNE	James River (RF)	VA	M	M	M
342	M1	27	Dry Cargo	AK	OCCIDENTAL VICTORY	Suisun Bay (RF)	CA	M	M	M
381	M1	28	Buoy Tender	WAGL307	PLANETREE	Suisun Bay (RF)	CA	O	M	M
344	M1	29	Dry Cargo		PVT FRED C. MURPHY	Beaumont (RF)	TX	M	M	M
345	M1	30	Dry Cargo	AK	QUEENS VICTORY	Suisun Bay (RF)	CA	M	M	M
348	M1	31	Dry Cargo	AK	RIDER VICTORY	Suisun Bay (RF)	CA	M	M	M
352	M1	32	Dry Cargo	AK	SANTA CRUZ	James River (RF)	VA	M	M	M
353	M1	33	Dry Cargo	AK	SANTA ELENA	James River (RF)	VA	M	M	M
356	M1	34	Dry Cargo	AK	SANTA ISABEL	James River (RF)	VA	M	M	M
364	M1	35	Dry Cargo	AK	SIOUX FALLS VICTORY	Suisun Bay (RF)	CA	M	M	M
365	M1	36	Transport & Pass-Cargo	AP	STATE	James River (RF)	VA	M	M	M
366	M1	37	Transport & Pass-Cargo	AP	TEXAS CLIPPER (I)	Beaumont (RF)	TX	M	M	M
368	M1	38	Dry Cargo	AK	WASHINGTON	James River (RF)	VA	M	M	M
456	M1	39	Dry Cargo	AK	WAYNE VICTORY	James River (RF)	VA	M	M	M
369	M1	40	Dry Cargo	AK	WINTHROP VICTORY	Suisun Bay (RF)	CA	M	M	M
466	M2	41	Tanker	AOT	ADONIS	Beaumont (RF)	TX	M	M	M
370	M2	42	Dry Cargo	AK	ADVENTURER	Suisun Bay (RF)	CA	M	M	M
374	M2	43	Dry Cargo	AK	AGENT	Suisun Bay (RF)	CA	M	M	M
375	M2	44	Dry Cargo	AK	AIDE	Suisun Bay (RF)	CA	M	M	M
376	M2	45	Dry Cargo	AK	ALLISON LYKES	Beaumont (RF)	TX	M	M	M
377	M2	46	Dry Cargo	AK	AMBASSADOR	Suisun Bay (RF)	CA	M	M	M
378	M2	47	Dry Cargo	ACS	AMERICAN BANKER	James River (RF)	VA	M	M	M
383	M2	48	Tanker		AMERICAN OSPREY	Beaumont (RF)	TX	M	M	M
384	M2	49	Dry Cargo	AK	AMERICAN RELIANCE	Suisun Bay (RF)	CA	M	M	M
385	M2	50	Dry Cargo		BANNER	Beaumont (RF)	TX	M	M	M
387	M2	51	Dry Cargo	AK	BAY	Suisun Bay (RF)	CA	M	M	M
388	M2	52	Dry Cargo	AKR	BAYAMON	James River (RF)	VA	M	M	M
389	M2	53	Dry Cargo	AK	BRINTON LYKES	Beaumont (RF)	TX	M	M	M
391	M2	54	Dry Cargo	AK	BUYER	Beaumont (RF)	TX	M	M	M
392	M2	55	Dry Cargo		CAPE ALAVA	James River (RF)	VA	M	M	M
394	M2	56	Dry Cargo		CAPE BON	Suisun Bay (RF)	CA	M	M	M
399	M2	57	Dry Cargo	AK	CAPE CANAVERAL	James River (RF)	VA	M	M	M
400	M2	58	Dry Cargo	AK	CAPE CANSO	James River (RF)	VA	M	M	M
401	M2	59	Dry Cargo	AK	CAPE CARTHAGE	James River (RF)	VA	M	M	M
403	M2	60	Dry Cargo		CAPE CATAWBA	Cheatham Annex	VA	M	M	M
404	M2	61	Dry Cargo	AK	CAPE CATOCHE	James River (RF)	VA	M	M	M
405	M2	62	Dry Cargo		CAPE CHALMERS	James River (RF)	VA	M	M	M
407	M2	63	Dry Cargo	AK	CAPE CHARLES	James River (RF)	VA	M	M	M
408	M2	64	Dry Cargo	AK	CAPE CLEAR	James River (RF)	VA	M	M	M
409	M2	65	RoRo		CAPE LAMBERT	Wilmington, NC	NC	M	M	M
411	M2	66	RoRo		CAPE LOBOS	Wilmington, NC	NC	M	M	M
413	M2	67	Combination		CAPE NOME	James River (RF)	VA	M	M	M
414	M2	68	Dry Cargo	AK	CATAWBA VICTORY	James River (RF)	VA	M	M	M
415	M2	69	RoRo		COMET	Alameda, CA	CA	M	M	M
463	M2	70	Dry Cargo		COURIER	Beaumont (RF)	TX	O	M	M
416	M2	71	Dry Cargo	AK	DAWN	Suisun Bay (RF)	CA	M	M	M
417	M2	72	Dry Cargo	AK	DEL MONTE	James River (RF)	VA	M	M	M
418	M2	73	Dry Cargo	AK	DEL VALLE	Beaumont (RF)	TX	M	M	M
419	M2	74	Dry Cargo	AK	DEL VIENTO	Beaumont (RF)	TX	M	M	M
420	M2	75	Tanker	AOT	FALCON LEADER	Beaumont (RF)	TX	M	M	M
382	M2	76	WAGB4	WAGB4	GLACIER	Suisun Bay (RF)	CA	O	M	M
421	M2	77	Dry Cargo		GULF BANKER	Beaumont (RF)	TX	M	M	M
422	M2	78	Dry Cargo	AK	GULF FARMER	Beaumont (RF)	TX	M	M	M
423	M2	79	Dry Cargo	AK	GULF MERCHANT	Beaumont (RF)	TX	M	M	M
424	M2	80	Dry Cargo	AK	GULF SHIPPER	Beaumont (RF)	TX	M	M	M
425	M2	81	Dry Cargo		GULF TRADER	Beaumont (RF)	TX	M	M	M
426	M2	82	Dry Cargo	AK	JAMES MCHENRY	James River (RF)	VA	M	M	M
427	M2	83	Dry Cargo		LAKE	James River (RF)	VA	M	M	M
428	M2	84	Tanker	AOT	LEXINGTON	Beaumont (RF)	TX	M	M	M

Table A.2 (continued)

NUMBER	CATEGORY		CLASS/TYPE	HULL	NAME	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER
431	M2	85	Dry Cargo	AK	LINCOLN	Suisun Bay (RF)	CA	M	M	M
432	M2	86	Dry Cargo	AK	MAGALLANES	Beaumont (RF)	TX	M	M	M
433	M2	87	Dry Cargo	AK	MALLORY LYKES	Beaumont (RF)	TX	M	M	M
434	M2	88	Tanker	AOT	MARYLAND	Beaumont (RF)	TX	M	M	M
469	M2	89	Tanker		MOUNT VERNON	Beaumont (RF)	TX	M	M	M
436	M2	90	Tanker		MOUNT WASHINGTON	Houston, TX	TX	M	M	M
470	M2	91	Dry Cargo		NORTHERN LIGHT	Suisun Bay (RF)	CA	M	M	M
438	M2	92	Dry Cargo	AKV	OHIO	Beaumont (RF)	TX	M	M	M
439	M2	93	Dry Cargo	AK	PAN AMERICAN VICTORY	Suisun Bay (RF)	CA	M	M	M
440	M2	94	Transport & Pass-Cargo	AP	PATRIOT STATE	James River (RF)	VA	M	M	M
441	M2	95	Tanker	AOT	PENNSYLVANIA TRADER	Beaumont (RF)	TX	M	M	M
442	M2	96	Dry Cargo		PIONEER COMMANDER	Beaumont (RF)	TX	M	M	M
443	M2	97	Dry Cargo		PIONEER CONTRACTOR	Beaumont (RF)	TX	M	M	M
444	M2	98	Dry Cargo	AK	PIONEER CRUSADER	Beaumont (RF)	TX	M	M	M
445	M2	99	Dry Cargo	AK	PRESIDENT	Suisun Bay (RF)	CA	M	M	M
446	M2	100	Dry Cargo	AK	PRIDE	James River (RF)	VA	M	M	M
447	M2	101	Tanker	AOT	PRIDE II	Beaumont (RF)	TX	M	M	M
450	M2	102	Tanker	AOC	SAGAMORE	Suisun Bay (RF)	CA	M	M	M
452	M2	103	Dry Cargo	AK	SANTA LUCIA	James River (RF)	VA	M	M	M
453	M2	104			SCAN	James River (RF)	VA	M	M	M
454	M2	105	Dry Cargo	AK	SHIRLEY LYKES	James River (RF)	VA	M	M	M
455	M2	106	Dry Cargo	AK	SOLON TURMAN	Suisun Bay (RF)	CA	M	M	M
457	M2	107	Passenger Ship	AGS	STATE OF MAINE	James River (RF)	VA	M	M	M
459	M2	108	Passenger Ship	AGS	TEXAS CLIPPER II	Beaumont (RF)	TX	M	M	M
396	N1	109	AO187	AO190	ANDREW HIGGINS	Suisun Bay (RF)	CA	N	M	N
97	N1	110	AD37	AD42	ACADIA	NISMF	HI	N	N	N
165	N1	111	LST1179	LST1190	BOULDER	NISMF	VA	N	N	N
2	N1	112	LKA113	LKA113	CHARLESTON	NISMF	VA	N	N	N
269	N1	113	CV63	CV64	CONSTELLATION	ACTIVE		N	N	N
30	N1	114	LKA113	LKA114	DURHAM	NISMF	HI	N	N	N
4	N1	115	LST1179	LST1182	FRESNO	NISMF	HI	N	N	N
192	N1	116	DD963	DD966	HEWITT	ACTIVE		N	N	N
272	N1	117	CV59	CV62	INDEPENDENCE			N	N	N
233	N1	118	DD963	DD981	JOHN HANCOCK	ACTIVE		N	N	N
101	N1	119	AO187	AO188	JOSHUA HUMPHREYS	NISMF	PA	N	N	N
100	N1	120	AS36	AS41	MCKEE			N	N	N
1	N1	121	LKA113	LKA115	MOBILE	NISMF	PA	N	N	N
215	N1	122	DD963	DD980	MOOSBRUGER	ACTIVE		N	N	N
203	N1	123	AD37	AD38	PUGET SOUND	NISMF	PA	N	N	N
29	N1	124	LST1179	LST1191	RACINE	NISMF	HI	N	N	N
273	N1	125	CV59	CV61	RANGER	NISMF	WA	N	N	N
263	N1	126	AFS1	AFS6	SAN DIEGO	NISMF	PA	N	N	N
59	N1	127	LKA113	LKA116	ST LOUIS	NISMF	HI	N	N	N
60	N1	128	LST1179	LST1187	TUSCALOOSA	NISMF	HI	N	N	N
398	N3	129	AO177	AO179	MERRIMACK	James River (RF)	VA	N	M	N
496	N3	130	AD14	AD19	YOSEMITE	James River (RF)	VA	N	M	N
96	N3	131	LST1179	LST1195	BARBOUR COUNTY	NISMF	HI	N	N	N
200	N3	132	DDG993	DDG994	CALLAGHAN	NISMF	WA	N	N	N
6	N3	133	DDG993	DDG996	CHANDLER	ACTIVE		N	N	N
253	N3	134	ARS5	ARS39	CONSERVER	NISMF	HI	N	N	N
14	N3	135	FFG7	FFG15	ESTOCIN	ACTIVE		N	N	N
13	N3	136	FFG7	FFG12	GEORGE PHILIP	ACTIVE		N	N	N
255	N3	137	ARS5	ARS40	HOIST	NISMF	VA	N	N	N
66	N3	138	FFG7	FFG14	JOHN H SIDES	ACTIVE		N	N	N
68	N3	139	DD963	DD973	JOHN YOUNG	ACTIVE		N	N	N
259	N3	140	TAGS26	TAGS27	KANE	ACTIVE		N	N	N
74	N3	141	DDG993	DDG993	KIDD	NISMF	PA	N	N	N
128	N3	142	LST1179	LST1179	NEWPORT	NISMF	VA	N	N	N
157	N3	143	LST1179	LST1183	PEORIA	NISMF	HI	N	N	N
71	N3	144	FFG7	FFG13	SAMUEL E. MORISON	ACTIVE		N	N	N
73	N3	145	DDG993	DDG995	SCOTT	NISMF	PA	N	N	N
10	N3	146	FFG7	FFG9	WADSWORTH	ACTIVE		N	N	N
65	N3	147	DE1052	DE1062	WHIPPLE	NISMF	HI	N	N	N
343	N4	148	TAO187	TAO192	HENRY ECKFORD	James River (RF)	VA	N	M	N
437	N4	149	TUGBOAT	YTM146	HOGA	Suisun Bay (RF)	CA	N	M	N
386	N4	150	LST1177	LST1171	LORAIN COUNTY	James River (RF)	VA	N	M	N
464	N4	151	Navy Drydock		SAN ONOFRE	Suisun Bay (RF)	CA	N	M	M
336	N4	152	EX LST963	ARL24	SPHINX	James River (RF)	VA	N	M	N
245	N4	153	CG26	CG31	STERETT	Suisun Bay (RF)	CA	N	M	N
340	N4	154	AGOS1	AGOS4	TRIUMPH	Suisun Bay (RF)	CA	N	M	N
144	N4	155	LPD4	LPD4	AUSTIN	ACTIVE		N	N	N
72	N4	156	DD963	DD979	CONOLLY	NISMF	PA	N	N	N
67	N4	157	CA134	CA134	DES MOINES	NISMF	PA	N	N	N
501	N4	158	CV59	CV59	FORRESTAL	NISMF	PA	N	N	N
69	N4	159	DE1052	DE1052	KNOX	NISMF	WA	N	N	N
502	N4	160	CV41	CV41	MIDWAY	NISMF	WA	N	N	N
78	N4	161	FFG7	FFG7	OLIVER HAZARD PERRY	NISMF	PA	N	N	N
280	N4	162	CV59	CV60	SARATOGA	NEWPORT	RI	N	N	N
471	N5	163	Tanker	AOG81	ALATNA	Tsuneishi, JAPAN		M	M	M
472	N5	164	Tanker	AO	AMERICAN EXPLORER	Beaumont (RF)	TX	M	M	M
372	N5	165	Barracks CRF	APL57	APL 57	James River (RF)	VA	N	M	M
270	N5	166	ARS5	ARS38	BOLSTER	Suisun Bay (RF)	CA	N	M	M
473	N5	167	Navy Oiler	AO98	CALOOSAHATCHEE	James River (RF)	VA	M	M	M
474	N5	168	Navy Oiler	AO99	CANISTEO	James River (RF)	VA	M	M	M

Table A.2 (continued)

NUMBER	CATEGORY		CLASS/TYPE	HULL	NAME	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER
185	N5	169	AS33	AS34	CANOPUS	James River (RF)	VA	N	M	M
475	N5	170	Dry Cargo		CAPE COD	James River (RF)	VA	M	M	M
476	N5	171	AOG81	AOG82	CHATTAHOOCHEE	Tsuneishi, JAPAN		M	M	M
119	N5	172	AO177	AO177	CIMARRON	Suisun Bay (RF)	CA	N	M	M
179	N5	173	ARS5	ARS33	CLAMP	Suisun Bay (RF)	CA	N	M	M
373	N5	174	Experimental Nav Ship	EAG153	COMPASS ISLAND	James River (RF)	VA	M	M	M
477	N5	175	EX German Salvage Barg	YHLC2	CRANDALL	James River (RF)	VA	M	M	M
478	N5	176	EX German Salvage Barg	YHLC1	CRILLEY	James River (RF)	VA	M	M	M
244	N5	177	LSD1	LSD20	DONNER	James River (RF)	VA	N	M	M
479	N5	178	EX TUSKEGEE VICTORY	AGS22	DUTTON	Beaumont (RF)	TX	M	M	M
390	N5	179	LSD36	LSD40	FORT FISHER	Suisun Bay (RF)	CA	N	M	N
480	N5	180	EX FURMAN VICTORY	AK281	FURMAN	Beaumont (RF)	TX	M	M	M
481	N5	181	AP120	AP122	GEN ALEXANDER M PATCH	James River (RF)	VA	M	M	M
482	N5	182	AP120	AP124	GEN EDWIN D PATRICK	Suisun Bay (RF)	CA	M	M	M
484	N5	183	EX AP145	AGM10	GEN HOYT S VANDENBERG	James River (RF)	VA	M	M	M
486	N5	184	AP110	AP110	GEN JOHN POPE	Suisun Bay (RF)	CA	M	M	M
487	N5	185	AP120	AP125	GEN NELSON M WALKER	James River (RF)	VA	M	M	M
402	N5	186	AP120	AP127	GEN WILLIAM O. DARBY	James River (RF)	VA	M	M	M
465	N5	187	AGS38	AGS38	H H HESS	Suisun Bay (RF)	CA	M	M	M
468	N5	188	AGS29	AGS32	HARKNESS	James River (RF)	VA	M	M	M
167	N5	189	AO143	AO145	HASSAYAMPA	Suisun Bay (RF)	CA	N	M	M
248	N5	190	CG26	CG30	HORNE	Suisun Bay (RF)	CA	N	M	N
186	N5	191	AS11	AS16	HOWARD W. GILMORE	James River (RF)	VA	N	M	M
187	N5	192	AS31	AS31	HUNLEY	James River (RF)	VA	N	M	M
168	N5	193	AO143	AO146	KAWISHIWI	Suisun Bay (RF)	CA	N	M	M
135	N5	194	ASR7	ASR13	KITTIWAKE		VA	N	M	M
406	N5	195	Ballistic Missile Supply	AK282	MARSHFIELD	James River (RF)	VA	M	M	M
410	N5	196	Tanker	AO	MAUMEE	Beaumont (RF)	TX	M	M	M
346	N5	197	EX AK278 SEA LIFT		METEOR	Alameda, CA	CA	M	M	M
347	N5	198	AOR1	AOR2	MILWAUKEE	James River (RF)	VA	M	M	M
429	N5	199	AK270	AK271	MIRFAK	James River (RF)	VA	M	M	M
435	N5	200	Tanker	AO105	MISPILLION	Suisun Bay (RF)	CA	M	M	M
349	N5	201	Tanker		MISSION BUENAVENTURA	Beaumont (RF)	TX	M	M	M
350	N5	202	Tanker		MISSION CAPISTRANO	Beaumont (RF)	TX	M	M	M
351	N5	203	Tanker	AO134	MISSION SANTA YNEZ	Suisun Bay (RF)	CA	M	M	M
169	N5	204	AO143	AO144	MISSISSENEWA	James River (RF)	VA	N	M	M
357	N5	205	AK270	AK272	MIZAR	James River (RF)	VA	M	M	M
120	N5	206	AO177	AO178	MONONGAHELA	James River (RF)	VA	N	M	M
483	N5	207	LSD28	LSD35	MONTICELLO	Suisun Bay (RF)	CA	N	M	N
112	N5	208	AE21	AE29	MOUNT HOOD	ACTIVE		N	M	M
170	N5	209	AO143	AO143	NEOSHO	James River (RF)	VA	N	M	M
182	N5	210	AS11	AS17	NEREUS	Suisun Bay (RF)	CA	N	M	M
358	N5	211	Tanker	AOG78	NODAWAY	Tsuneishi, JAPAN		M	M	M
180	N5	212	ARS5	ARS41	OPPORTUNE	James River (RF)	VA	N	M	M
183	N5	213	AS11	AS18	ORION	James River (RF)	VA	N	M	M
188	N5	214	ASR21	ASR22	ORTOLON	James River (RF)	VA	N	M	M
359	N5	215	Tanker	AO105	PAWCATUCK	James River (RF)	VA	M	M	M
189	N5	216	ASR7	ASR14	PETREL	James River (RF)	VA	N	M	M
123	N5	217	AO177	AO186	PLATTE	James River (RF)	VA	N	M	M
247	N5	218	LSD28	LSD31	POINT DEFIANCE	Suisun Bay (RF)	CA	N	M	M
360	N5	219	ex AKD1, POINT BARROW	AGDS	POINT LOMA	Suisun Bay (RF)	CA	M	M	M
171	N5	220	AO143	AO148	PONCHATOULA	Suisun Bay (RF)	CA	N	M	M
271	N5	221	ARS5	ARS8	PRESERVER	James River (RF)	VA	N	M	M
361	N5	222	AGR1	AGR11	PROTECTOR	James River (RF)	VA	M	M	M
184	N5	223	AS11	AS19	PROTEUS	Suisun Bay (RF)	CA	N	M	M
362	N5	224	AF58	AF58	RIGEL	James River (RF)	VA	M	M	M
172	N5	225	AO49	AO155	ROANOKE	Suisun Bay (RF)	CA	N	M	M
363	N5	226	Tanker	AO75	SAUGATUCK	James River (RF)	VA	M	M	M
126	N5	227	AOR1	AOR4	SAVANNAH	James River (RF)	VA	N	M	M
448	N5	228	Tanker	AO151	SHOSHONE	Suisun Bay (RF)	CA	M	M	M
449	N5	229	AK284	AK285	SOUTHERN CROSS	James River (RF)	VA	M	M	M
181	N5	230	AS11	AS12	SPERRY	Suisun Bay (RF)	CA	N	M	M
246	N5	231	LSD28	LSD32	SPIEGEL GROVE	James River (RF)	VA	N	M	M
191	N5	232	ASR7	ASR15	SUNBIRD	James River (RF)	VA	N	M	M
458	N5	233	Tanker	AO62	TALUGA	Suisun Bay (RF)	CA	M	M	M
485	N5	234	LSD28	LSD28	THOMASTON	Suisun Bay (RF)	CA	N	M	N
393	N5	235	LST1156	LST1158	TIOGA COUNTY	Suisun Bay (RF)	CA	N	M	N
460	N5	236	Tanker	AO147	TRUCKEE	James River (RF)	VA	M	M	M
461	N5	237	Military Auxiliary	LKA	TULARE	Suisun Bay (RF)	CA	M	M	M
136	N5	238	LPD1	LPD2	VANCOUVER	NISMF	HI	N	N	M
494	N5	239		TAG194	VANGUARD	James River (RF)	VA	M	M	M
177	N5	240	AR5	AR5	VULCAN	James River (RF)	VA	N	M	M
175	N5	241	AOR5	AOR5	WABASH (EX AOR 5)	Suisun Bay (RF)	CA	N	M	M
462	N5	242	Tanker	AO109	WACCAMAW	James River (RF)	VA	M	M	M
250	N5	243	LST1156	LST1162	WAHKIAKUM COUNTY	Suisun Bay (RF)	CA	N	M	M
176	N5	244	AOR1	AOR1	WICHITA	Suisun Bay (RF)	CA	N	M	M
122	N5	245	AO177	AO180	WILLAMETTE	Suisun Bay (RF)	CA	N	M	M
251	N5	246	LST1171	LST1178	WOOD COUNTY	James River (RF)	VA	N	M	M
93	N5	247	AD37	AD43	CAPE COD	James River (RF)	VA	N	M	M
503	N5	248	LPD5	LPD9	DENVER	ACTIVE		N	N	N
90	N5	249	AS36	AS37	DIXON		VA	N	N	M
274	N5	250	LPD4	LPD6	DULUTH	ACTIVE		N	N	N
91	N5	251	ARS5	ARS6	ESCAPE	NISMF	PA	N	N	M
106	N5	252	ASR7	ASR9	FLORIKAN	NISMF	HI	N	N	M

Table A.2 (continued)

NUMBER	CATEGORY		CLASS/TYPE	HULL	NAME	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER
260	N5	253	APA128	APA168	GAGE	NISMF	VA	N	N	N
493	N5	254	AS31	AS32	HOLLAND	Suisun Bay (RF)	CA	N	M	M
138	N5	255	AR5	AR8	JASON	NISMF	WA	N	N	M
137	N5	256	AOR1	AOR6	KALAMAZOO	James River (RF)	VA	N	M	M
495	N5	257	AOR1	AOR3	KANSAS CITY	NISMF	WA	N	N	M
142	N5	258	AS36	AS36	L Y SPEAR		VA	N	N	M
261	N5	259	AE21	AE23	NITRO	NISMF	PA	N	N	N
204	N5	260	LPD4	LPD5	OGDEN	ACTIVE		N	N	N
278	N5	261	AE21	AE24	PYRO	NISMF	WA	N	N	M
262	N5	262	APA128	AGM23	RANGE SENTINEL	NISMF	PA	N	N	N
505	N5	263	ARS5	ARS42	RECLAIMER	NISMF	HI	N	N	M
31	N5	264	AD37	AD37	SAMUEL GOMPERS	NISMF	VA	N	N	M
121	N5	265	AD37	AD44	SHENANDOAH		VA	N	N	M
18	N5	266	LPD6	LPD12	SHREVEPORT	ACTIVE		N	N	N
58	N5	267	AE21	AE21	SURIBACHI	NISMF	PA	N	N	M
267	N5	268	AFS1	AFS2	SYLVANIA	NISMF	PA	N	N	M
109	N5	269	AFS1	AFS4	WHITE PLAINS	NISMF	PA	N	N	M
178	N5	270	AGS26	AGS34	WYMAN	NISMF	HI	N	N	M
145	N5	271	AD37	AD41	YELLOWSTONE		VA	N	N	M
252	N8	272	CG16	CG22	ENGLAND	Suisun Bay (RF)	CA	N	M	N
141	N8	273	CG26	CG33	FOX	Suisun Bay (RF)	CA	N	M	N
26	N8	274	CG16	CG21	GRIDLEY	Suisun Bay (RF)	CA	N	M	N
395	N8	275	LPH2	LPH7	GUADALCANAL	NISMF	PA	N	M	N
19	N8	276	CG16	CG23	HALSEY	Suisun Bay (RF)	CA	N	M	N
20	N8	277	CG26	CG29	JOUETT	Suisun Bay (RF)	CA	N	M	N
24	N8	278	DE1052	DE1060	LANG	Suisun Bay (RF)	CA	N	M	N
21	N8	279	CG16	CG16	LEAHY	Suisun Bay (RF)	CA	N	M	N
163	N8	280	AGOR3	AGOR7	LYNCH	James River (RF)	VA	N	M	M
161	N8	281	AE21	AE22	MAUNA KEA	Suisun Bay (RF)	CA	N	M	M
27	N8	282	DE1052	DE1058	MEYERKORD	Suisun Bay (RF)	CA	N	M	N
173	N8	283	AOG10	AOG10	NEMASKET	Suisun Bay (RF)	CA	N	M	M
355	N8	284	CV9	CV34	ORISKANY	Beaumont (RF)	TX	N	M	N
492	N8	285	AGOR3	AGOR3	ROBERT D. CONRAD	James River (RF)	VA	N	M	N
22	N8	286	DDG2	DDG9	TOWERS	Suisun Bay (RF)	CA	N	M	N
174	N8	287	AOG4	AOG4	WABASH (EX AOG 4)	Suisun Bay (RF)	CA	N	M	M
25	N8	288	CG26	CG32	WILLIAM H STANDLEY	Suisun Bay (RF)	CA	N	M	N
367	N8	289	YTB752	YTB785	WINNEMUCCA	Suisun Bay (RF)	CA	N	M	N
380	N8	290		•	YC 1471	Suisun Bay (RF)	CA	N	M	N
164	N8	291	YFNB5	YFNB5	YFNB 5	Suisun Bay (RF)	CA	N	M	N
143	N8	292	Barge	YC824		Suisun Bay (RF)	CA	N	M	N
89	N8	293	Barge	YC826		Suisun Bay (RF)	CA	N	M	N
283	N8	294	MSO421	MSO511	AFFRAY		VA	N	N	N
281	N8	295	CV63	CV66	AMERICA	NISMF	PA	N	N	N
102	N8	296	DD963	DD968	ARTHUR W RADFORD	ACTIVE		N	N	N
98	N8	297	FFG7	FFG34	AUBREY FITCH	NISMF	PA	N	N	N
104	N8	298	DDG2	DDG6	BARNEY	NISMF	PA	N	N	N
105	N8	299	DDG2	DDG22	BENJAMIN STODDERT	NISMF	HI	N	N	N
7	N8	300	CG26	CG34	BIDDLE	NISMF	PA	N	N	N
279	N8	301	MHC43	MHC43	BITTERN	NISMF	PA	N	N	N
160	N8	302	DD963	DD970	CARON	ACTIVE		N	N	N
212	N8	303	DDG2	DDG5	CLAUDE V RICKETTS	NISMF	PA	N	N	N
219	N8	304	DDG2	DDG21	COCHRANE	NISMF	HI	N	N	N
202	N8	305	DD963	DD974	COMTE DE GRASSE	NISMF	PA	N	N	N
8	N8	306	DLG6	DLG40	COONTZ	NISMF	PA	N	N	N
211	N8	307	DLG6	DLG43	DAHLGREN	NISMF	PA	N	N	N
218	N8	308	DD963	DD971	DAVID R RAY	ACTIVE		N	N	N
158	N8	309	DD966	DD989	DEYO	ACTIVE		N	N	N
223	N8	310	DE1052	DE1070	DOWNES	NISMF	WA	N	N	N
225	N8	311	DE1040	DE1043	EDWARD MCDONNELL	NISMF	PA	N	N	N
9	N8	312	DD965	DD967	ELLIOTT	ACTIVE		N	N	N
282	N8	313	MSO421	MSO433	ENGAGE	NISMF	PA	N	N	N
504	N8	314	MSO421	MSO440	EXPLOIT		VA	N	N	N
275	N8	315	MSO421	MSO441	EXULTANT		VA	N	N	N
498	N8	316	DLG6	DLG37	FARRAGUT	NISMF	PA	N	N	N
99	N8	317	MSO421	MSO446	FORTIFY		VA	N	N	N
239	N8	318	DE1052	DE1067	FRANCIS HAMMOND	NISMF	WA	N	N	N
17	N8	319	LPH2	LPH9	GUAM		VA	N	N	N
227	N8	320	DE1052	DE1074	HAROLD E HOLT	NISMF	HI	N	N	N
499	N8	321	CG16	CG17	HARRY E YARNELL	NISMF	PA	N	N	N
220	N8	322	DD963	DD986	HARRY W HILL	NISMF	HI	N	N	N
237	N8	323	DE1052	DE1055	HEPBURN	NISMF	WA	N	N	N
199	N8	324	MSO421	MSO449	IMPERVIOUS	NISMF	PA	N	N	N
241	N8	325	DD963	DD990	INGERSOLL	NISMF	HI	N	N	N
193	N8	326	DD963	DD983	JOHN RODGERS	NISMF	PA	N	N	N
159	N8	327	DD964	DD965	KINKADE	ACTIVE		N	N	N
231	N8	328	DDG2	DDG4	LAWRENCE	NISMF	PA	N	N	N
209	N8	329	DD963	DD984	LEFTWICH			N	N	N
207	N8	330	DLG6	DLG38	LUCE	NISMF	PA	N	N	N
500	N8	331	DLG6	DLG39	MACDONOUGH	NISMF	PA	N	N	N
210	N8	332	DLG6	DLG42	MAHAN	NISMF	PA	N	N	N
208	N8	333	DD963	DD976	MERRILL	NISMF	HI	N	N	N
221	N8	334	DD963	DD975	O'BRIEN	ACTIVE		N	N	N
222	N8	335	DD963	DD964	PAUL F FOSTER	ACTIVE		N	N	N
224	N8	336	DLG6	DLG46	PREBLE	NISMF	PA	N	N	N

Table A.2 (continued)

NUMBER	CATEGORY		CLASS/TYPE	HULL	NAME	STORAGE SITE	STATE	ORIGINATOR	CUSTODIAN	TITLE HOLDER
206	N8	337	DE1052	DE1057	RATHBURNE	NISMF	HI	N	N	N
11	N8	338	DE1052	DE1053	ROARK	NISMF	WA	N	N	N
217	N8	339	SSR572	SS572	SAILFISH	NISMF	WA	N	N	N
5	N8	340	DDG2	DDG10	SAMPSON	NISMF	PA	N	N	N
226	N8	341	DDG2	DDG11	SELLERS	NISMF	PA	N	N	N
232	N8	342	FFG7	FFG31	STARK			N	N	N
229	N8	343	CG26	CG28	WAINWRIGHT	NISMF	PA	N	N	N
190	N9	344	ASR21	ASR21	PIGEON	Suisun Bay (RF)	CA	N	M	M
195	N9	345	PG84	PG90	CANON	Panama City	FL	N	N	N
201	N9	346	PG84	PG94	CHEHALIS	Panama City	FL	N	N	N
216	N9	347	DD931	DD936	DECATUR	Port Hueneme	CA	N	N	N
194	N9	348	PG84	PG100	DOUGLAS	Panama City	FL	N	N	N
196	N9	349	PG84	PG85	GALLOP	Panama City	FL	N	N	N
198	N9	350	PG84	PG98	GRAND RAPIDS	Panama City	FL	N	N	N
234	N9	351	ATA121	ATA203	NAVIGATOR	MDSU ONE		M	N	N
243	N9	352	SS572	SS573	SALMON	New London	CT	N	N	N
16	N9	353	LSD1	LSD15	SHADWELL	Mobile	AL	N	N	N
197	N9	354	SS563	SS566	TROUT	Key West	FL	N	N	N
284	N9	355	AG193	AG193	GLOMAR EXPLORER	HOUSTON	TX	O	O	N
264	N9	356	AGOS1	AGOS10	INVINCIBLE	MSC		N	O	N
285	N9	357	TATF166	TATF166	POWHATTAN	DON JON		N	O	N
277	N9	358	LPH2	LPH10	TRIPOLI	Loan to Army		N	O	N

KEYS:

CATEGORIES:
N1 - NAVY MOBILIZATION AND OTHER RETENTION ASSETS
N2 - NAVY EXISTING FOREIGN MILITARY LEASES
N3 - NAVY POTENTIAL FUTURE FMS AND GRANTS
N4 - NAVY POTENTIAL DONATIONS OR COMMERCIAL LEASES
N5 - FORMER NAVY VESSELS, TITLE TRANSFERED TO MARAD FOR DISPOSITION
N6 - NAVY SINKEX CANDIDATES
N7 - NAVY HELD FOR SPARE PARTS
N8 - NAVY READY FOR DISPOSAL, HELD AT NISMFS OR MARAD
N9 - NAVY SPECIAL VESSELS
N10 - NAVY MUSEUM SHIPS
M1 - MARAD VESSELS ON MARAD INVENTORY - READY FOR DISPOSAL
M2 - MARAD VESSELS ON MARAD INVENTORY - MILITARY RETENTION, SPARE PARTS, ETC., SHIPS THAT ARE UNLIKELY TO BE RETAINED

ORIGINATOR, CUSTODIAN, TITLE HOLDER

	MARAD	Navy	Other Organization
Originator of the Vessel (Originator)	M	N	O
Current Custodian of the Vessel (Custodian)	M	N	O
Current Title Holder of the Vessel (Title Holder)	M	N	O

Appendix B

ESTIMATING THE AMOUNT OF RECYCLABLE MATERIALS AND WASTES IN DOMESTIC SHIP RECYCLING

Ship recycling is principally a subset of the scrap metal industry. While warships and merchant ships also contain such reusable equipment as diesel engines, galley equipment, pumps, pipes, and valves, about 90 percent of the total value of an old ship in domestic markets is in the metals that can be removed, reduced to mill-grade materials, and sold for remelting and reforming into other metal products. Overseas recyclers, particularly those in Asia, recycle more equipment and materials and use more metals directly without remelting than do U.S. recyclers. Warships and merchant ships contain nearly every form of metal available in worldwide commerce. Ultra-high strength nickel alloys, stainless steel, titanium, and other high-value metals can be found in some parts of nearly all warships, but they are present in such small quantities that recovery and resale are not necessarily cost-effective.

PRIMARY RECYCLABLE METALS

Four types of metals represent the bulk of the scrap-metal value in a ship: steel, aluminum, copper and copper alloys, and lead. Steel remains the most common metal used in the structure of ships, and armor plate is (except in the case of small, specialized craft) the most common scrap species present. Many varieties of steel are used in ships—including high-strength steels, mild steel, stainless steel, and many cast iron forgings—each with its own value in the recycled metal market. We did not have the information necessary to estimate how much of each type can be recovered from each type of ship. We therefore combined all varieties into a single "steel" category.

Some warships use aluminum as the major structural metal in the deckhouse. It is also used in some Navy ships for internal joinerwork bulkheads, deck plates, ventilation ducting, and other services to reduce the overall weight of the ship.

Copper and copper alloys are used in electrical systems in all ships and in seawater pipes and components in many Navy ships. We explored the idea of estimating copper amounts based on installed electric plant capacity but could find no relationship from the available data. Undoubtedly, the 61 diesel electric and turboelectric drive ships in Table A.1 that have large copper-based electric propulsion systems will have notable amounts of copper aboard. However, we found no data to suggest a proper copper recovery fraction for such ships. Because of this, the total copper recovery for the fleet may be underestimated. There also was no consistent rule that would allow us to estimate copper as distinct from its alloys. Both are treated as one aggregate quantity.

Because lead is dense, it is the most common ballast material in warships. However, because it is more costly than other, bulkier ballast materials such as concrete, drilling mud, and water, it is rarely used in merchant ships. Ships may also have many pounds of lead in the form of lead-based paint and solder in electrical equipment, but these forms have little or no value in recycling markets.

Market prices for scrap metals are very erratic, varying widely month by month and by where in the United States the recycler is attempting to sell the scrap.

REUSABLE EQUIPMENT

The value of reusable equipment such as motors and bollards varies widely as well and depends on both the item's market worth and the recycler's resourcefulness in identifying and exploiting the markets.

WASTE MATERIALS

Ships also contain waste materials, i.e., materials that have no value in any domestic recycling market. Wastes can include fabrics, small manufactured items such as switches and motors that cost more to reduce to scrap than the scrap is worth, sludges from tanks, paint flakes, gaskets, thermal and acoustic insulation, and detritus generated during the recycling process.

LIGHT SHIP WEIGHT

We used as-built LSW as the reference figure for estimating the amounts of salable scrap and reusable items and waste materials. The per-ship and total LSWs used in this analysis are presented in Appendix A, Table A.1, along with an explanation of the table's origins and development. The amounts of recoverable scrap and waste are expressed as a percentage of LSW. Use of LSW as the scaling variable is subject to the following four caveats:

1. **Fuels and lubricants.** LSW includes the weight of the ship's entire structure, its hardware, and its propulsion working fluids but does not include the weight of fuel, payload, lubricants, personnel, and personnel effects. Most if not all Navy warships under the cognizance of the Navy's Inactive Ship Maintenance Facilities have had residual fuels and lubricants removed. Some ships under the cognizance of MARAD have fuel and lubricant residuals aboard. The weight of fuels and lubricants is not reflected in the LSWs used in our analysis. MARAD examined three ships in its Retired Ship inventory for the number of tanks full or partly full of fuels or lubricants.[1] Based on the assumption that all tanks with measurable fuels or lubricants are full, the ships in this sample average about 0.2 tons of residuals per ton of LSW.

   The value of residual fuels and lubricants in the domestic marketplace depends on the quantity, purity, and locale of the disposal. Most often, residual fuels and lubricants must be analyzed to determine their purity and hence their market value. Analysis of fuels is itself expensive and often reveals impurities, such as rust and water, that reduce the material's value. Thus, ship owners usually must pay to have the materials removed. At best, an owner can expect no more than $29 per ton for well-pedigreed materials.[2] The ships in the MARAD sample thus would have a residuals value ranging from negative to no more than $6 per ton of LSW. Because there is no consistent way to estimate the amount—short of reviewing individual tank soundings for each ship and analyzing the contents for purity—we did not consider the potential value of residual fuels and lubricants.

2. **LSW growth.** The LSWs listed in Table A.1 are the as-designed LSWs reflected in the references cited in Appendix A. A warship typically grows in weight during construction and its service life by as much as 10 percent above as-built weight as it takes on different missions and mission hardware during its life. Thus, at the end of its service life, a ship will weigh a slightly different amount than nominally identical ships of the same class. This source of error leads to underestimates of actual LSWs by as much as 10 percent. We generally did not include possible LSW growth in the analysis, because it falls within the uncertainty of other factors we used.

3. **Propulsion fluids.** LSWs include up to several tons of propulsion system water that has no economic value. The amount of this water is greater in steam-propelled ships than in ships propelled by diesel or gas turbines. This

[1]MARAD, *Survey of Ships and Materials*, Report MA-ENV-820-96003-E, January 1997, p. 45.

[2]Dollar amount is courtesy of the Fuels Division of Systech Environmental Corporation, Dayton, OH.

factor leads to slight overestimates of the actual weight of valuable materials in a ship. We did not include a correction for this small effect.

4. **LSW loss.** During a ship's service life, corrosion will cause a loss of metal. In U.S. warships, this loss is slight because of the very high maintenance standards commonly employed. However, in merchant ships, corrosion loss during service life can add up to 10 percent or even more.[3] This is because merchant ships typically have large surface areas exposed to weather and sea and because they are less well maintained than Navy ships, particularly during their last five years of life.[4] Additionally, tankers have potentially corrosive cargo. Corrosion loss is seen in a ship's final steel weight measurements during the recycling process; it varies by a factor of two or more from ship to ship depending on the quality of the ship's maintenance during its life. While this factor is important to the individual recycler, we ignored it in our analysis because it is not predictable.

SHIP WEIGHT BREAKDOWNS

To determine the value inherent in a ship's salable scrap species, we need estimates of the amounts of the principal species present in each type of ship. We prepared estimates using data from three key sources:

1. The U.S. Naval Sea Systems Command (NAVSEA) provided estimates of the metals contained in two classes of destroyers, an aircraft carrier, and nuclear-powered submarines.
2. The Naval Institute Press publishes comprehensive histories of U.S. destroyers, cruisers, and aircraft carriers that include weight breakdown data for many types of ships. These weight breakdowns are not by type of metal, but by service in the ship (hull and structure, propulsion, and so forth). This information allowed us to make informed judgments about the amounts of each principal species that would be present. Although not all Navy ship types in Table A.1 were covered, there was enough information to provide a basis for reasonable estimates for all warships.

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[3]Ferrous Scrap Committee, Ministry of Steel, Government of India, *Shipbreaking Industry—Present Status in India and Its Impact on Environment*, Vol. I, August 1997, pp. 2–14.

[4]Commercial ships are required to undergo a comprehensive inspection every three to five years. Normally, at the 20- or 25-year inspection point, owners find that the cost of the inspection and anticipated repairs exceeds the value of the ship on the scrap market, and the ship is sold for scrap. During the last five years of a ship's life, many owners anticipate scrap sale and thus minimize maintenance, which leads to extensive corrosion loss.

3. For merchant ships, we used data from sources describing ship recycling in India and from a MARAD source that estimates the recoverable fractions from recycling of U.S. merchant ships.

The data from these three sources are discussed in more detail in the following three sections.

NAVSEA Data [5,6,7,8]

The data from the NAVSEA sources are summarized in Table B.1.[9] For the destroyers and the carrier, the data include only ship structure and electrical systems. Ballast information is available for the destroyers but not for the carrier. The balance of the "missing" weight in these ships is in propulsion and weapons machinery, habitability systems, and other nonstructural materials, much of which represents recyclable metals nonetheless. The submarine data are complete. The "missing" weight in the submarine data, about 9 percent of the total, represents nonrecyclable wastes such as insulation, floor tiles, and fiberboard scrap resulting from recycling the ship.

Table B.1

Materials Weight Data from NAVSEA Sources (percentage of LSW)

	DDG2	DDG37	DDG Average	CV 59	Submarines
Steel	31	33	32	72	52
Aluminum	5	4	5	0.01	1.4
Copper and copper alloys					
Copper	2	1	3	1	1.4
Brass and bronze	1	1	3	1	7
Cu-Ni	0.3	0.2	3	1	No data
Ballast lead	3	5	4	No data	29
LSW accounted for	41	43	43	73	90.8

5Philadelphia Naval Shipyard letter, Ser. No. 93-098, August 12, 1993 (DDG2 data).

6Charleston Naval Shipyard letter, Ser. No. 248/261, September 16, 1993 (DDG37 data).

7Norfolk Naval Shipyard letter 4010(244.1), 244.1-L2-94, March 31, 1994 (CV59 data).

8"U.S. Nuclear Powered Submarine Inactivation, Disposal and Recycling," 1995, submarine data. These data are for recycled nuclear submarines minus their nuclear systems. We use these metal percentages for estimating the materials recovery for conventional submarines in the inactive fleet.

9All of the weight data in this table and the tables in the next two sections (i.e., Tables B.1 through B.9) are in long tons (1 LT = 2,240 pounds). Note that the data do not add to 100 percent of LSW.

The 3 percent figure for copper and copper alloys in the DDGs agrees fairly well with the reported recovery of 3.5 percent of LSW (116 tons) from the recycling of the ex-USS *Patterson* (DE1061) in 1999–2000.[10] The same source reports recovery of 461 tons of aluminum, or about 14 percent of the ship's LSW—a figure that does not agree with the *Patterson* results.

Naval Institute Press Data[11,12,13,14]

Tables B.2 through B.6 present the separate data for steam-powered destroyers, steam-powered cruisers, gas-turbine-powered frigates and destroyers, aircraft carriers, amphibious ships, and battleships that were available from the Naval Institute Press sources. Table B.7 summarizes the data by ship type. These data are not by metal species but by Engineering Ship Work Breakdown Structure (ESWBS) in the seven system groups corresponding to the Navy's ESWBS weight control system:

Group 1: Hull and structure

Group 2: Propulsion

Group 3: Electrical

Group 4: Command and surveillance

Group 5: Auxiliaries

Group 6: Outfitting

Group 7: Armament

In a few instances, the Naval Institute Press data included margin allowances (for future weight growth). We included these. Note that the totals in Tables B.2 through B.7 do not always add to 100 percent. This is due to rounding of the entries and the fact that the source data often did not add to 100 percent (no reasons were stated).

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[10]Kristina Henry, "Shipbreaking May Mend Marine Yard," *Baltimore Sun*, May 14, 2000.

[11]Bernard Prezelin, *The Naval Institute Guide to Combat Fleets of the World, 1990/1991*, Naval Institute Press, 1990.

[12]Norman Friedman, *U.S. Destroyers, An Illustrated Design History*, The Naval Institute Press, 1982.

[13]Norman Friedman, U.S. *Battleships, An Illustrated Design History*, Naval Institute Press, 1984.

[14]Norman Friedman, *U.S. Aircraft Carriers, An Illustrated Design History*, Naval Institute Press, 1983.

Table B.2

Materials Weight Data from Naval Institute Press Sources, Steam-Powered Destroyers (percentage of LSW)

ESWBS	DD445 *Fletcher* (2,035 LSW tons)	DE 1040 *Garcia* (2,441 LSW tons)	DD931 *Forrest Sherman* (2,734 LSW tons)	DE1052 *Knox* (3,020 LSW tons)	DDG2 *Adams* (3,277 LSW tons)	Steam DD/DE Avgs.
1: Hull and structure[a]	36	45	35	47	37	40
2: Propulsion	34	14	26	14	25	23
3: Electrical	4	4	4	4	4	4
4: Cmd/surv	3	6	3	7	5	5
5: Aux	9	13	13	13	11	12
6: Outfitting	7	9	8	9	8	8
7: Armament[b]	7	4	10	5	8	7
Margin[c]	—	4	—	—	—	4

[a]For carriers and battleships using the old weight system, hull and structure includes hull fittings and armor.

[b]For carriers, armament includes defensive weapons systems and features needed to accommodate aircraft.

[c]Margin is available only for the DE1040 Class.

Table B.3

Materials Weight Data from Naval Institute Press Sources, Steam-Powered Cruisers (percentage of LSW)

ESWBS	CG16 *Leahy* (5,146 LSW tons)	CG 26 *Belknap* (5,409 LSW tons)	Steam CG Avgs.
1: Hull and structure	45	46	46
2: Propulsion	18	17	18
3: Electrical	4	4	4
4: Cmd/surv	7	7	7
5: Aux	11	11	11
6: Outfitting	7	8	8
7: Armament	7	6	7
Margin	—	—	

Table B.4

Materials Weight Data from Naval Institute Press Sources, Gas-Turbine Powered Frigates and Destroyers (percentage of LSW)

ESWBS	FFG7 *Perry* (2,648 LSW tons)	DD963 *Spruance* (5,826 LSW tons)	Gas Turbine DD/FF Avgs.
1: Hull and structure	47	53	50
2: Propulsion	10	13	12
3: Electrical	4	5	5
4: Cmd/surv	4	6	5
5: Aux	17	13	15
6: Outfitting	12	8	10
7: Armament	4	3	4
Margin	—	—	

Table B.5

Materials Weight Data from Naval Institute Press Sources, Aircraft Carriers (percentage of LSW)

			CV59 *Forrestal*			
ESWBS	CV9 *Essex* (24,074 LSW tons)	CV41 *Midway* (42,215 LSW tons)	Old Weight System (55,587 LSW tons)	New Weight System (55,528 LSW tons)	CV63 *Kitty Hawk* (60,005 LSW tons)	CV Avgs.[a]
1: Hull and structure	81	81	84	68	64	66
2: Propulsion	13	12	11	6	7	7
3: Electrical	N/A	N/A	N/A	2	2	2
4: Cmd/surv	N/A	N/A	N/A	1	1	1
5: Aux	N/A	N/A	N/A	15	14	15
6: Outfitting	2	2	2	6	5	6
7: Armament	4	5	2	2	2	2
Margin	—	—	—	—	7	4

NOTE: NA indicates that weights were not available. By inspection, we concluded that the weights for these three ESWBS groups were included in the ESWBS group 1, hull and structure.

[a]Averages for CVs are based on the new weight system data for *Forrestal* and *Kitty Hawk*. New system weight breakdowns are not available for the older carriers.

Table B.6

Materials Weight Data from Naval Institute Press Sources, Amphibious Ships and Battleships (percentage of LSW)

ESWBS	LPH 9 *Guam* (11,280 LSW tons)	LHA 1 *Tarawa* (25,588 LSW tons)	L-Ship Avgs.	BB61 *Iowa* (43,944 LSW tons)
1: Hull and structure	60	63	62	81
2: Propulsion	5	5	5	10
3: Electrical	2	3	3	N/A
4: Cmd/surv	2	2	2	N/A
5: Aux	15	14	15	N/A
6: Outfitting	10	9	10	1
7: Armament	1	1	1	8
Margin	—	—		—

Table B.7

Summary of Naval Institute Press Ship Weight Data (percentage of LSW)

ESWBS	Steam DD/DE Avgs.	Steam CG Avgs.	Gas Turbine DD/FF Avgs.	CV Avgs.[a]	L-Ship Avgs.	BB61 *Iowa*
1: Hull and structure	40	46	50	66	62	81
2: Propulsion	23	18	12	7	5	10
3: Electrical	4	4	5	2	3	N/A
4: Cmd/surv	5	7	5	1	2	N/A
5: Aux	12	11	15	15	15	N/A
6: Outfitting	8	8	10	6	10	1
7: Armament	7	7	4	2	1	8
Margin	4	—	—	4	—	—

[a]Averages for CVs are based on the new weight system data for *Forrestal* and *Kitty Hawk*. New-system weight breakdowns are not available for the older carriers.

Merchant Ship Data[15,16,17]

Our information on recyclables from merchant ships is from recycling yards in India and estimates made by MARAD for domestic recycling of merchant ships. No actual return data are available from the U.S. recycling industry for small merchant ships. Table B.8 shows the data from Indian recycling. Note that the scrap species are different than those discussed above in that steel is largely recovered as reroll plate: steel plates that are rerolled into new sheet metal products without first being remelted. This is a common practice in Asia but nearly unheard-of in the United States. The nonferrous metals shown in Table B.8 are nearly all copper and copper alloys. Very small amounts of aluminum are also occasionally recovered from merchant ships. The information in the table represents average recovery results from the recycling of approximately 1,700 ships of all kinds at Alang, India, over more than 10 years.

Indian ship recyclers recycle all but about 3 percent of the as-received ship. The difference between this figure and those in Table B.8 represents the amount of a ship's original as-built LSW that is lost to corrosion during its service life. These figures appear in Table B.8's Weight Lost column.

Table B.8

Recoverable Materials Weight Data from Indian Recyclers (percentage of LSW)

Type of Vessel	Reroll Scrap	Melting Scrap	Cast Iron	Non–ferrous Metals	Machinery	Furniture and Misc.	Weight Lost
General cargo	56-70	10	2-5	1	4-8	5	9-15
Bulk carrier	61-71	8-10	2-3	1	2-5	1-5	10-16
Ore carrier	62-69	10	3	1	3-5	5	10-16
Passenger	44-58	10	5	1-2	10-15	5-7	11-17
Oil tanker	72-81	5-7	2-3	1-2	1-2	1-2	10-12
Ore/bulk oil carrier	66-75	8-10	3	1	1-6	1-2	10-13
Naval ships	53-67	10	2-6	1-2	4-6	1-2	15-22
Container ship	63-67	10	3-4	1	5	5	10-13
Fishing vessel	47-67	10	3-8	1-2	2-10	5	12-18
Average	64	9	4	1	5	4	13

[15]Ferrous Scrap Committee, Ministry of Steel, Government of India, *Comprehensive Environmental Impact Assessment and Environmental Management Plan,* August 1997.

[16]Ferrous Scrap Committee, Ministry of Steel, Government of India, *Shipbreaking in India, A Roadmap for Future Development,* undated (circa spring 1999).

[17]MARAD, *The Markets, Cost and Benefits of Ship Breaking/Recycling in the United States,* Report MA-ENV-820-96003-E, January 1997.

The MARAD estimates are for the amount of recoverable scrap species from standard types of MARAD-design merchant ships. These estimates are shown in Table B.9

Table B.9

MARAD Estimates of Recoverable Materials from U.S. Merchant Ships

Scrap Species	Percentage of LSW
Ferrous	93.5
Copper and copper alloys	1
Waste	5.5

ESTIMATING THE AMOUNT OF RECYCLABLE SCRAP SPECIES AND WASTE FROM LSW DATA

By synthesizing the data above, we developed reasonable estimates of both the percentage of scrap metals that can be recovered and the waste produced during recycling. All are expressed as a recovery index in percentage of LSW.

The data above suggest that there are some differences in the recovery rates for different types of ships. We thus decided to classify Navy and U.S. Coast Guard ships in nine categories and MARAD merchant ships in one category:

- Navy and USCG ships
  1. Surface combatants (SC)
  2. Surface combatants with aluminum deckhouses (SCA)
  3. Aircraft carriers (CV)
  4. Battleships (BB)
  5. Submarines (SUB)
  6. Amphibious warfare (AMP)
  7. Auxiliaries (AUX)
  8. Mine warfare (MINE)
  9. Other (OTH)
- MARAD merchant ships (including all other miscellaneous ships)

We used the ship types identified in Appendix A, Table A.1 under Ship Type. For Navy ships, the ship type is one of the nine abbreviations listed above. All USCG vessels are listed as OTH, as are all Navy craft and dry-docks. For MARAD merchant ships and miscellaneous ships, we used the specific MARAD

ship type designation (such as T2-S or C3-S-33b), or PRVT if there was no MARAD designation for the ship, or country of origin if there was no other type information available from MARAD.

The available information on waste generation comes from NAVSEA data for submarine recycling (9 percent), the Indian recycling shown in Table B.8 (13 percent), and the MARAD data shown in Table B.9 (5.5 percent). We chose to use the average of these data (9 percent) for the waste generated in recycling all ship types shown in Appendix A, Table A.2.

The recovery indices developed for the scrap species and waste involved in recycling the different types of ships are given in Table B.10. Details on the indices of the various ship types are provided below. These indices were used to determine the scrap metal value of the different types of ships. We assumed that all battleships would become museums and thus did not include them in our working inventory.

Table B.10

Recovery Indices for Ship Types

	Ferrous	Aluminum	Copper and Copper Alloys	Lead	Waste
Surface combatants	79	4	4	4	9
Aircraft carriers	85	1	1	4	9
Submarines	53	1	8	29	9
Amphibious warfare	85	1	1	4	9
Auxiliaries	85	1	1	4	9
Mine warfare	Nil	Nil	Nil	Nil	Nil
Merchant ships	90	0	1	0	9
Other ships	90	0	1	0	9

Surface Combatants

For ferrous scrap weight, we used the sum of the ESWBS weight groups 1, 2, 5, and 7 in Table B.7 averaged over the table's three types of surface combatants adjusted for aluminum and waste generation. We also adjusted the ferrous index to float as necessary to make the sum of all fractions equal to 100. Regarding aluminum, we were advised by NAVSEA that all surface combatants listed in Table A.2 as derived from the *Forrest Sherman* (DD931 Class) employed aluminum deckhouses. *Forrest Sherman* was built in 1955, and only five of the 70 surface combatants in Table A.2 were built before 1955. We concluded that it was adequate to treat all of this class as post-1955 ships and thus applied the aluminum index (4) to all of them. The NAVSEA data, as shown in Table B.1, were used for indices for aluminum (4), copper and copper alloys (4), and lead (4).

Aircraft Carriers

For the CV ferrous index, we used the sum of the Naval Institute Press data in Table B.7 for ESWBS groups 1, 2, 5, and 7, floated as necessary to make the total index equal to 100. This gives a ferrous index of 85. The aluminum estimate for carriers in Table B.1, the *Forrestal*, is surprisingly small (0.01 percent). In most modern warships, aluminum is used for interior joinerwork bulkheads, doors and doorframes, deck plates, and many other services—the goal being to reduce the vessel's overall weight. We estimated that an aluminum index of 1 is adequate to represent these sources. For copper and copper alloys, we used the NAVSEA estimate of 1 percent. We believe this is reasonable for aircraft carriers because their steel hull and structures are truly massive, including armor plate and multiple side protection systems. This mass of steel diminishes the fraction of their total displacement devoted to nonferrous materials. For lead, the average of the data in Table B.1 (4 percent) was used; for waste, 9 percent was used, as before.

Submarines

For submarines, we used the rounded NAVSEA data from Table B.1. This approach may be subject to notable error because nuclear and conventional submarines are very different vessels. However, the nuclear submarine data were the only data available. Because the number of conventional submarines awaiting disposal is small, any errors have little influence on the total recoverable metals represented by the inactive fleet.

Amphibious Warfare and Auxiliaries

For ferrous scrap for amphibious warfare ships, we used the sum of ESWBS weight groups 1, 2, 5, and 7 for these ships in Tables B.6 and B.7, floated as necessary to make the total index equal to 100. Amphibious warfare ships carry large numbers of U.S. Marines. Aluminum is used in these ships in the same manner and extent as in heavily manned aircraft carriers. Therefore, we chose an index of 1 for this specie. Copper and copper alloys were estimated from the ESWBS weight information in Tables B.2 through B.4 and Table B.6. In Tables B.2 through B.4, the sums of the propulsion and electrical ESWBS groups range from 17 to 27 percent of LSW, whereas in Table B.6 these categories add to only 8 percent for amphibious warfare ships. This reflects the smaller propulsion and electrical systems found in amphibious warfare ships compared with surface combatants. We concluded that a copper and copper alloys index of about one-third that of surface combatants, or 1, is appropriate. For lead, we used the same index used for surface combatants.

For Naval auxiliary ships, there are no weight data on which to base recovery fractions. However, we know that many if not all Naval auxiliary ships identified by the Navy or MARAD as being to a Navy design would have been constructed in accordance with "General Specifications for Ships of the United States Navy,"[18] which means standard Navy design practices, such as the use of copper alloys in seawater systems and lead ballasting, would have been employed. Also, as is evident in Appendix A, Table A.1, Navy auxiliaries have power densities in the 100s of tons per shaft horsepower, comparable to Navy amphibious ships. (Warships have power densities in the tens of tons per shaft horsepower.) Based on this evidence, we concluded that the recovery fraction for amphibious ships is also appropriate for Naval auxiliaries.

Mine Warfare

Mine warfare ships are constructed of wood or nonmetallic hulls and nonmagnetic interior equipment made from metals such as copper and certain stainless steels. Their recovery indices are therefore very different from those of a warship or Naval auxiliary.

As of this writing, several of the mine warfare ships recently in the Navy inventory have been disposed of. And in Appendix A, Table A.2, only six such vessels remain, totaling only 4,404 tons of LSW. This constitutes less than 0.2 percent of the total LSW of the ships in Table A.2. We thus decided not include to material recovery from mine warfare ships in this analysis.

Other Ships and Merchant Ships

We treated all other vessels and all merchant ships (including miscellaneous ships) the same. While this may be incorrect for specialized small vessels such as patrol craft and tugboats, there are so few of these and their total LSW is so small (less than 1 percent of the total LSW of the disposal candidates in the analysis) that the error introduced is equally small. Table B.8 shows the recovery of materials during recycling of ships in India. For the average merchant ship, about 82 percent of its LSW is recovered as ferrous species, 1 percent as nonferrous species (mostly copper and alloys), and 4 percent as reusable furnishings. Thirteen percent is lost as waste, and 10 percent of that 13 percent represents corrosion loss relative to as-built LSW. Most of the 4 percent of the LSW that is reusable furnishings is items such as old furniture, window glass, door frames, and floor coverings—items reusable in India but not in the United States and thus that would become waste. As for the MARAD waste estimate, it

[18]NAVSEA S9AAO-AA-SSPN-010/GEN-SPEC, 1983 Edition.

is low compared to other information. We used an overall average figure of 9 percent for waste among all types of ships.

Compared to the Indian data in Table B.8, the MARAD information in Table B.9 shows the same copper and copper alloys recovery (1 percent), no notable aluminum or lead recovery, and proportionally more ferrous scrap (93.5 percent). We concluded that for other ships and MARAD merchant ships, the MARAD metal recovery data are appropriate except that steel recovery was reduced to accommodate the higher waste estimate.

RECOVERY OF MARKETABLE COMPONENTS AND ARTIFACTS

The MARAD information also notes that about 10 percent of the total market value of a scrap ship is in the resale of reusable equipment such as fire pumps and motors, galley equipment, bollards, anchors and anchor chain, and artifacts such as hatch covers (from Liberty ships, made into furniture). In estimating the total value of a ship, this source of revenue is included by dividing the total scrap metal value by 0.9—i.e., ($ value of scrap metal) ÷ 0.9 = ($ total recoverable value of a ship).

SUMMARY OF RECOVERY INDICES

Indices for recyclable materials and waste recovery were developed for the Navy and MARAD vessels in Appendix A, Table A.2, using Navy and MARAD documentation and published literature. These indices, shown in Table B.10, were then used to determine the scrap metal values for recycled ships.

THE VALUE OF SCRAP METAL[19]

The values used for the calculations are shown in Table B.11 in dollars per long ton and, for all but steel, dollars per pound. After applying these prices to the recoverable scrap metal fractions of each type of ship and dividing by 0.9 to account for the value of equipment sold for continued use, we found that for domestic recycling the average Navy ship has a recovery value of $88 per long ton and the average merchant ship has a recovery value of $64 per long ton. These are average values based on recent prices for scrap metals. The prices for all metals are near their decade-long low. If prices go up, the recovery value of a ship could double; if they continue to decline, recovery value could drop even further. Table B.12 summarizes the average recoverable value from Navy and

[19]Appendix D addresses scrap prices in detail.

Table B.11

Average Value of Recovered Scrap Species

	Steel	Aluminum	Copper and Copper Alloys	Lead
$/long ton	53	725	972	213
$/pound	N/A	0.324	0.434	0.095

Table B.12

Average Recoverable Value of Ships in Domestic Recycling

	Weighted Avg. $/Ton	
Material	Navy Ships	Merchant and Other Ships
Steel	44	48
Aluminum	11	0
Copper and copper alloys	16	10
Lead	8	0
Total scrap metal	79	58
Equipment	9	6
Total	88	64

merchant ships based on the selected scrap prices. The totals do not add because of rounding.

SUMMARY AND CONCLUSIONS

Steel is the dominant scrap species in recycling Navy and MARAD ships, so the market value of scrap steel, presently at a low level, is the major determinant of a ship's value. For Navy ships, copper, aluminum, and lead are important contributors to value. In merchant ships, however, steel is the single dominant species, the value of copper is more modest (about 16 percent of steel value), and there is no aluminum or lead of note. The total estimated average value of the recoverable species from recycling is $88 per long ton for a Navy ship and $64 per long ton for a merchant ship, and each of these values vary by as much as ±50 percent in as little as a year.

Appendix C

POLYCHLORINATED BIPHENYLS IN VESSELS

Polychlorinated biphenyls (PCBs) are a class of synthetic organic chemicals consisting of from one to ten chlorine atoms (hence the *polychlorinated*) bonded to two joined six-member carbon rings (called a biphenyl molecule) that create up to 209 possible variations, or "congeners," of polychlorinated biphenyls. PCB products are normally mixtures of several congeners adjusted by the manufacturer to impart specific bulk properties to the compound. The congeners with the least chlorine present are oily liquids. As the amount of chlorine in these liquids increases, the product becomes progressively thicker, up to a solid wax. The ability to vary the viscosity, coupled with other favorable industrial properties, made PCBs a broadly useful compound in industry and in many commercial products.

PCBs are not corrosive themselves and, unlike many other oils and waxes, are very resistant to decomposition into corrosive compounds. They also have a high heat capacity and a high boiling point, do not conduct electricity, are non-flammable, and have a very low acute toxicity. For these reasons, from the time they were first introduced in 1929, PCBs quickly became the standard coolant and dielectric in the electric utility industry and the preferred hydraulic and cooling fluid in all industries. They were used as coolant and dielectric in electrical transformers and high-capacity electric transmission cables, as dielectrics in capacitors and small transformers, and as hydraulic fluids and cutting oils in all manner of industrial machinery in virtually every nation of the world.

Their variable viscosity and the fact that they do not dry out and become hard almost regardless of their environment led to another use for PCBs: as plasticizers and sealing agents in products such as rubber and plastics (particularly in the ubiquitous polyvinyl chloride [PVC] plastic), adhesives, paints, inks, gaskets, sealing compounds, and carrier fluids for pesticides, and as a mounting fluid for microscope slides. Historically, about 60 percent of all PCBs produced were

used as dielectric fluids, about 12 percent as hydraulic and heat transfer fluids, and about 28 percent as ingredients in manufactured products.[1]

Because PCBs are so common in the processing equipment of many product-manufacturing industries, many resulting products contain small amounts of PCBs picked up during their production. Examples include PCBs in extruded plastic and rubber products from use of PCB oil as an extrusion lubricant. Thus, PCBs can be found both as a functional and a tramp constituent of many products.

PCBs were manufactured in many countries: the United States (Monsanto was the only U.S. manufacturer), Austria, China, Czechoslovakia, France, Germany, Italy, Japan, the USSR and the Russian Federation, Spain, and the United Kingdom. Manufacturing stopped in the United States in 1979 but continued in many other countries well into the 1980s. Today, PCBs continue to be manufactured and exported for industrial use in some countries.[2]

Because PCBs are such chemically stable compounds, they do not degrade in the environment and they persist for decades, moving up the food chain by adsorption in lower life forms and ultimately in humans. PCBs can be found in trace amounts throughout the earth's biosphere, even in sediments on the bottom of the deepest oceans. They can be found in high concentrations in sediments and soils near places of their manufacture, use, and disposal. PCBs in human tissue are believed to be associated with an elevated risk of cancer and with other, noncancer abnormalities and are therefore coming under increasing regulation worldwide. While highly resistant to decomposition, PCBs are not immune. In a fire or at very high temperatures such as are seen in a kitchen frying pan, PCBs will decompose to, among other compounds, the extraordinarily toxic family of chemicals called dioxins.

PCB REGULATION

PCB regulation in the United States began in 1976 with the enactment of the Toxic Substances Control Act. This law and its implementing EPA regulations found at 40CFR761 led to a ban on the manufacture of PCBs in the United States in 1977 and to bans on imports, exports, and unrestricted use. In subsequent years, PCBs were gradually phased down in domestic industry but were not completely phased out.

[1] *Guidelines for the Identification of PCBs and Materials Containing PCBs*, United Nations Environment Programme, First Issue, August 1999.

[2] "POPS Profile Information Reporting Form," Slovak Republic, UNEP Chemicals.

It was not until the mid-1980s and later that West European nations began to place restrictions on the manufacture and use of PCBs. For example, the United Kingdom initiated regulations in 1986, Finland in 1990. Some European and Asian countries continue to manufacture and use PCBs today. This continued use in many foreign countries appears to have led to incorporation of PCBs in domestic products from imported feedstock, presumably unbeknownst to U.S. manufacturers.

International regulation of PCBs is now the subject of discussions within the UN Environment Programme. This work began in 1998 and is directed toward development of a new international treaty that would ban or control the manufacture and use of PCBs and nine other chemicals.[3] Although no agreement has yet been reached, notionally this work will lead to a ban on the continued manufacture of PCBs and to restrictions on the continued use of existing stocks, with the result that PCBs will ultimately disappear from the marketplace.

PCBs IN NAVY SHIPS

The Navy has followed the EPA's PCB regulations since they were first issued in the late 1970s. Consistent with the EPA regulations at the time, Navy actions focused on PCBs first in heavy electrical equipment (such as yard transformers ashore) and later on PCBs in small capacitors and transformers in shipboard electronic equipment.[4] During the early years of PCB regulation, the Navy noted that a unique military lubricant and anti-foulant used on the cables of some naval mines contained a high concentration of PCBs as required by its military specification. This problem—believed to be the only case of a Navy product containing PCBs as required by a military specification—was addressed in the early 1980s. It was not until 1989 that the Navy discovered during the course of normal occupational safety work at a shipyard, that PCBs also occurred in many plastics, rubbers, adhesives, gaskets, and other commercial nonmetal products used in Navy ships. Similar PCB-bearing products were subsequently found in use in many non-Navy facilities and structures.

NAVSEA has been sampling for PCBs in Navy ships since the early 1990s. Sampling has been done to determine whether ships and craft to be disposed of contain PCBs that must be considered in the disposal process. Shipyards sample during maintenance on ships to determine whether the products removed during maintenance require handling as PCB-materials and to de-

[3]PCBs are one of ten "persistent organic pollutants," or POPs, that are the subject of future international regulation. Most of the other POPs are pesticides, e.g., DDT.

[4]With very few exceptions, Navy ships do not carry and never did carry large electrical transformers such as those used by electrical utilities and shore-based heavy industry sites.

termine whether work processes must be amended to accommodate the presence of PCBs. Data from this sampling process have been assembled by NAVSEA 00T into four databases. We analyzed these databases (current through May 2000) to estimate the frequency with which PCBs can be found in Navy ships. The results are shown in Table C.1.

Table C.1 shows that 28 percent of all retired Navy ships (see Appendix A, Table A.1) have been sampled in some manner for PCBs and that of these, 77 percent contain PCBs above 50 ppm in at least one material—the limit at which stringent regulation begins. Of the 113 Navy ships ready for disposal (category N8 in Table C.1), 50 have been sampled and all 50 were found to contain regulated levels of PCBs.

All of the 83 ships reportedly containing PCBs were sampled comprehensively for PCBs in liquids (hydraulic fluids and lubricants) and a variety of solid materials such as rubber, paint, and tape. Of the 25 sampled ships found with no PCBs, only two were sampled in the same manner. Twenty-three were sampled only for PCBs in liquids or for liquid PCBs on surfaces. PCBs are rarely found in shipboard liquids, probably because such liquids are frequently replaced during routine maintenance and PCB-free replacements have normally been used since the late 1970s. Thus, only two of 85 comprehensively sampled ships (or approximately 2 percent) revealed no regulated PCBs. What this means, thus, is that up to 98 percent of all the Navy ships awaiting disposal may contain regulated amounts of PCBs in solid materials.

Table C.1

Analysis of PCBs for Navy and MARAD Retired Ship Assets[a]

Ship Category	Total No. of Ships in Category	Ships Sampled		With PCBs	
		No.	%	No.	%
N1: Navy mobilization and other retention assets	31	7	23	1	14
N2: Existing foreign military leases	26	0	0	N/A	N/A
N3: Potential future FMS and grants	39	8	21	3	38
N4: Potential donations or commercial leases	16	4	25	3	75
N5: Former Navy ships title-transferred to MARAD for disposition	87	24	28	14	58
N6: SINKEX candidates	9	6	67	5	83
N7: Held for spare parts	4	2	50	1	50
N8: Navy title vessels, ready for disposal, held at NISMFs or MARAD	113	50	44	50	100
N9: Special vessels	12	1	8	1	100
N10: Museum ships	51	6	10	5	83
Totals	388	108	28	83	77

[a]The complete list of ships is in Appendix A, Table A.1.

While the fact that PCBs are rarely found in shipboard fluids leads us to assume that newer ships may have less PCB material present than older ships do, there is not enough information in the databases for the ships in Table A.1 to validate this assumption. The newest ship listed in Table A.1 as having been sampled (and only for fluids) is *Shenandoah* (AD44), launched in 1982. No PCBs were found. The newest ship in which PCBs in solid materials were found is USS *Estocin* (FFG15), launched in 1979. The average launch date for the ships in Table A.1 is 1960.

PCBs IN MARAD SHIPS

In 1995, three MARAD ships in the ready-for-disposal inactive fleet were sampled comprehensively for PCBs and other hazardous materials: SS *Wayne Victory*, SS *Export Challenger*, and SS *Shirley Lykes*. PCBs were sampled in accordance with a then-new EPA shipboard sampling guide,[5] and the results were published in a MARAD report and its many appendices.[6] One of these appendices reported that PCBs were found in many different solid materials in the three ships but in none of the liquids.[7]

A sampling of three of the many MARAD ships in storage does not provide conclusive evidence for the presence or absence of PCBs in the MARAD ships listed in Table A.1. However, the fact that the three sampled MARAD ships revealed PCBs in the same types of materials that are used in Navy ships does indicate that the problem of shipboard PCBs is not unique to the Navy.

PCBs IN OTHER MERCHANT SHIPS

PCBs are regularly encountered during recycling of merchant ships. B. D. Ghosh reports up to 800 kilograms of PCBs in the paint of merchant ships recycled in India in recent years and also reports PCBs in electric cables and other materials.[8] India's Ferrous Scrap Committee reports that there are PCBs in many materials in the commercial ships recycled at the Alang, India, yards but that none were found in the environment surrounding the yard.[9]

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[5]Environmental Protection Agency, *Sampling Ships for PCBs Regulated for Disposal*, Interim Final Policy, November 30, 1995.

[6]MARAD, *Environmental Assessment of the Sale of National Defense Reserve Fleet Vessels for Scrapping*, Report MA-ENV-820-96003, July 1997.

[7]MARAD, *Survey of Ships and Materials*, Report MA-ENV-820-96003-F, January 1997.

[8]B. D. Ghosh, "Shipbreaking Industry in India: Present Status and Future Prospects," 1999, included as Appendix B in Ferrous Scrap Committee, Ministry of Steel, Government of India, *Shipbreaking in India, A Roadmap For Future Development*, undated (circa spring 1999).

[9]Ferrous Scrap Committee, Ministry of Steel, Government of India, *Shipbreaking Industry—Present Status in India and Its Impact on Environment*, Vol. I, August 1997.

Each year, recycling yards in India perform about 40 percent of all merchant ship recycling in the world. The average age of these ships is about 25 years, so most were built in the mid-1970s. All manner of merchant ships from a wide variety of ship operators and ship builders are recycled. The Ferrous Scrap Committee reports that PCBs are still in use in India and other countries but are being phased out at this time. The Committee thus expects the incidence of PCBs encountered during ship recycling to decline over the coming years.

THE COST OF MANAGING PCBs DURING RECYCLING

PCB management can be a notable cost in U.S. ship recycling because of the very strict rules that prohibit burning of PCB-bearing materials and require their disposal in specialized landfills. Ship recycling is a very labor-intensive operation, and the process of identifying and managing PCB-bearing materials can add significantly to the labor requirements.

Appendix D

SCRAP METAL PRICES

Scrap metal is any primary metal or alloy that has been used in a device and then recovered for reprocessing and subsequent reuse in another application. When scrap metal has been reprocessed and, as is often the case, combined with newly mined ore, it is considered once again a primary metal and can command a far higher price than it could as scrap. Technically, primary metals are unalloyed metals such as iron, copper, aluminum, and lead. Very often, metal alloys can be of more value than the primary metals themselves. Iron and copper are most often marketed as alloys. Copper alloys, brass and bronze, have been sold in the scrap market for millennia. More recently, alloys of iron, steels of various mechanical properties, have been marketed for subsequent combination with primary metals.

Figure D.1 shows the average weekly U.S. production of steel. As can be seen, total U.S. steel production, some of which is from scrap steel, has been highly variable but has remained at about 2 million long tons per week. Also shown in the figure is the average weekly steel production of the major producers: Pittsburgh, PA, Chicago, IL, and the western United States. These production values average from 200,000 to 500,000 tons per week.

The total rate of U.S. steel production is about 90 percent of the total U.S. steel production capacity, as shown in Figure D.2. These numbers are important to the recycling of Navy and MARAD vessels because they establish that the material introduced to the scrap steel market via ship recycling would not saturate the demand and thus depress scrap metal prices. We estimate that the inventory of ships will introduce about 150,000 tons of scrap steel per year. With the markets being several orders of magnitude larger, this amount will not change the U.S. price of steel.

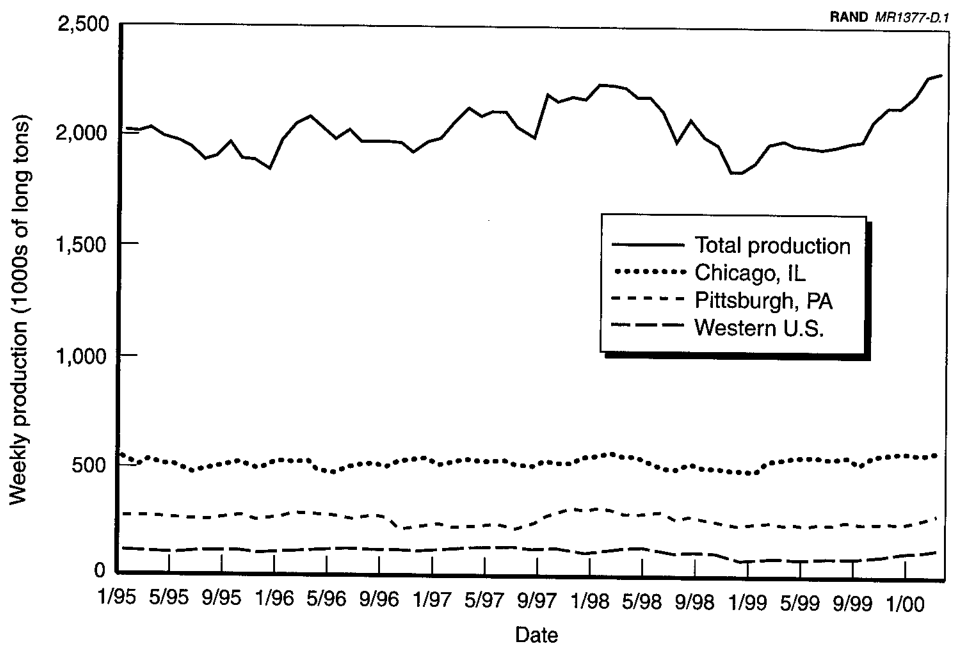

Figure D.1—Average Weekly U.S. Steel Production

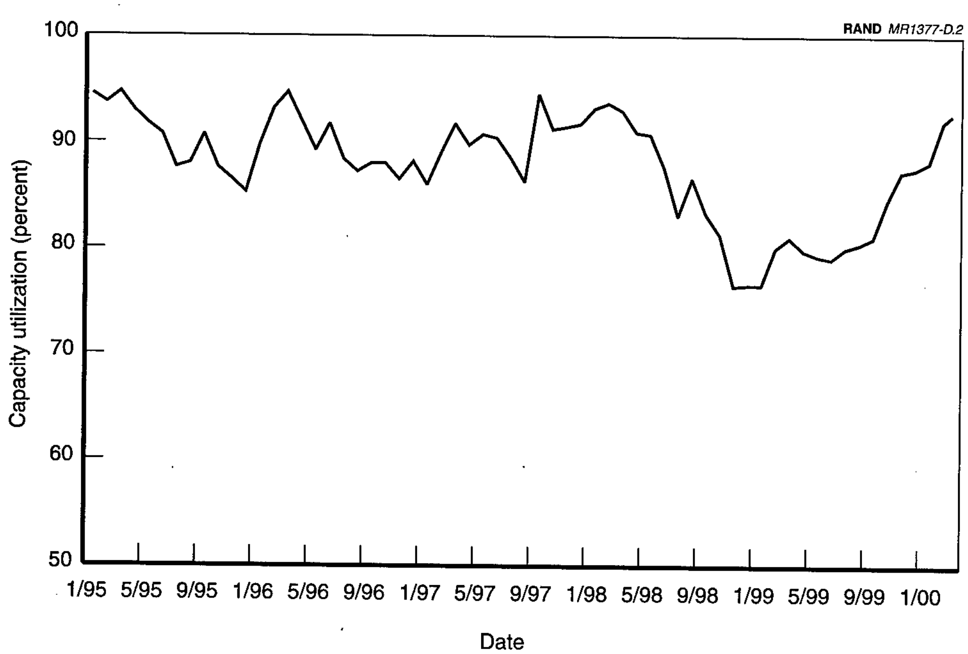

Figure D.2—Utilization of U.S. Steel Production Capacity

FERROUS SCRAP METAL PRICES

Scrap metal prices depend on the scrap class of the metal, whether the scrap is delivered to a broker or directly to a mill, and the city in which the scrap is traded.[1] The more than 100 classes of ferrous scrap depend on the size and thickness of the steel pieces in the lot and the source of the steel (e.g., automobiles, railroad equipment, steel cans). For our analysis we selected heavy melting No. 2 steel 5 feet × 18 inches or under.[2] No matter the grade of steel, the material must be free of dirt, nonferrous metals, foreign material of any kind, and excessive rust and corrosion. The requirement excluding foreign material does not apply to the accidental inclusion of negligible amounts of foreign material where the amount is unavoidable in normal preparation of the alloy. How the steel scrap is delivered has an enormous impact on price. If it is delivered to the steel mill directly on railroad cars in many ton lots rather than to the yard of a broker or exporter it will bring a higher price. The reason for this difference is that the broker or exporter has to incur further transportation costs and must have an allowance profit built into its prices for the raw scrap material. Price will also depend on the city in which the scrap is traded—i.e., the price is directly related to the trading city's proximity to the mills in which the scrap will be processed. In Pittsburgh, Philadelphia, and Chicago, mills are relatively close. Scrap delivered freight on board (FOB) to these cities can command a far higher price than can scrap delivered to San Francisco, Seattle, or Houston, where a broker or exporter is directly available but the mills are much further away.

Figure D.3 illustrates this relationship, plotting the average monthly price for heavy melting No. 2 steel scrap for the past five years for the six cities just mentioned. The very pronounced difference between the East Coast and West Coast cities is evident. Also evident are the volatility of the price and the price's general trend of decline since 1995. The average monthly price in October 2000 in Houston, Pittsburgh, and Chicago was about \$80 to \$90, whereas in Philadelphia it was \$60 and on the West Coast it was about \$20.[3] All of these prices are in U.S. dollars per long ton FOB mill or broker yard. If a shipbreaker delivers the scrap in the form of modules to a middleman so that it can be further reduced in size for scrap mill processing, the prices decline by roughly half.

To establish an estimate of the scrap steel price for further analysis, we selected prices at cities representative of those that would be likely to handle the shipbreaking of the Navy and MARAD ships: San Francisco, Houston, and Philadel-

[1] *Scrap Price Bulletin*, Cahners Publishing, 2000.

[2] See Scrap Recycling Institute, Scrap Specifications Circular, 1998.

[3] Ibid.

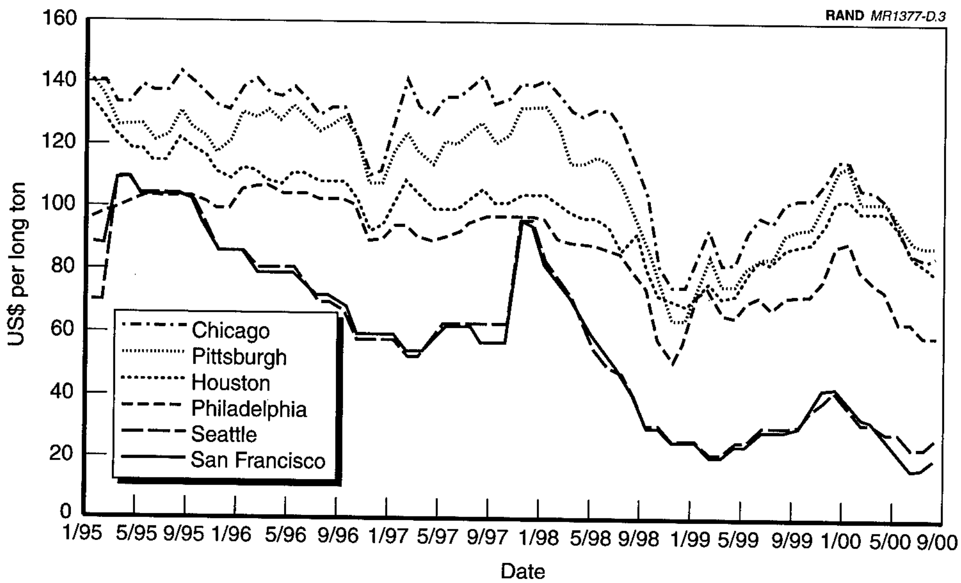

Figure D.3—Average Monthly U.S. Prices for Heavy Melting No. 2 Steel Scrap

phia. We selected Philadelphia over Pittsburgh despite the former's scrap price being depressed because the additional transportation costs to Pittsburgh of up to $20 per ton could offset the price difference. Moreover, many of the ships in the inactive inventory are stored near Philadelphia and nearby Baltimore. In the average, the Philadelphia price was weighted by a factor of two to account for the abundance of nearby ships. Using October 2000 average prices resulted in a location-weighted average of $53 in current U.S. dollars per long ton for mill-size scrap delivered to the mill. The price for modules delivered to a middleman is half this amount.

NONFERROUS SCRAP METAL PRICES

In addition to ferrous alloys, the Navy and MARAD ships contain nonferrous metals and alloys—aluminum, copper, copper alloys, and lead. Figure D.4 shows the average monthly price for the different classes of aluminum delivered to mills and dealers. Primary metal commands the highest price because, in contrast to the scrap classes, it can be directly used in fabrication. Prices for the scrap classes depend on whether the aluminum is cast or sheet; for the time period shown, they did not vary appreciably. As was true for the ferrous metals, the dealer price for aluminum is below all the prices shown. We selected an

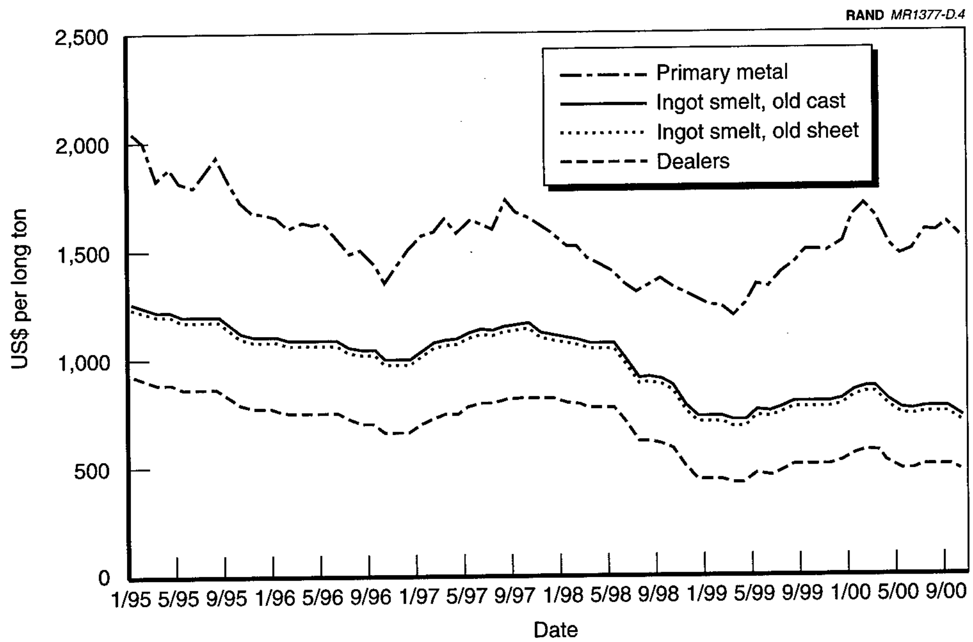

Figure D.4—U.S. Average Monthly U.S. Prices for Aluminum Scrap

average value for aluminum scrap based on the average October 2000 prices: $725 in current U.S. dollars per long ton.[4]

For copper we selected the heavy melt No. 2 copper scrap classification as the best descriptor of the copper scrap available from ships.[5] This classification covers all heavy copper scrap, including heavy wiring and buss bars as well as copper tubing all free of excessive tinning.

Figure D.5 shows the average monthly price for this class of copper for the past five years. As was the case for aluminum, the primary metal commands the highest price and the other classes of scrap command less, how much less depending on the smelter. The unusual property of the price trends here is that the copper scrap prices at the dealer and at the mill are about the same, indicating a more direct connection between scrap price and the primary metal price than was seen for the ferrous alloys. We adopted an average of the October 2000 prices: $1,047 in current U.S. dollars per long ton.

Copper alloys (brass and bronze) have many and diverse applications in ships—everything from manganese-bronze propellers to Monel valve stems and cop-

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[4]Ibid.

[5]Ibid.

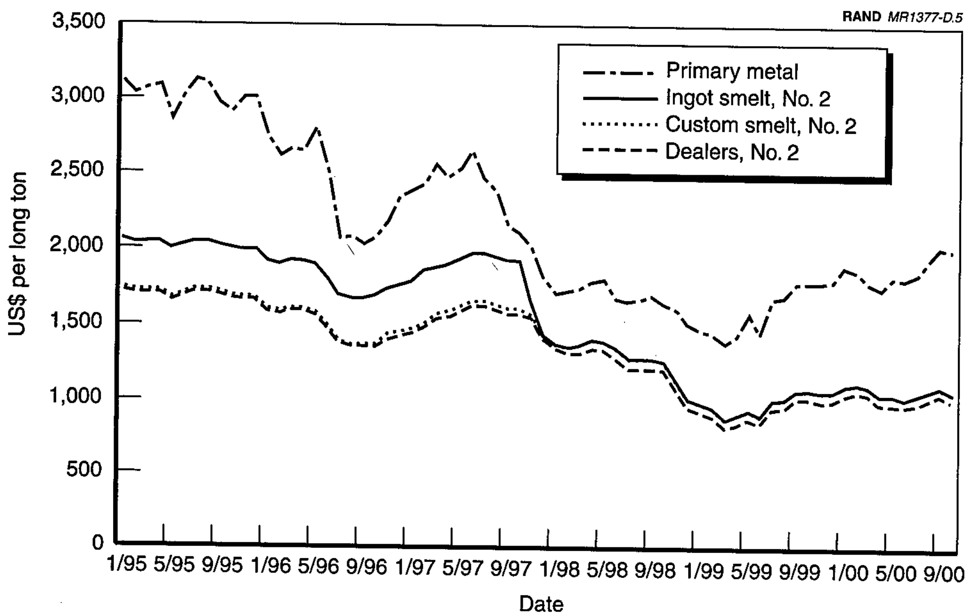

Figure D.5—Average Monthly U.S. Prices for Heavy Melt No. 2 Copper Scrap

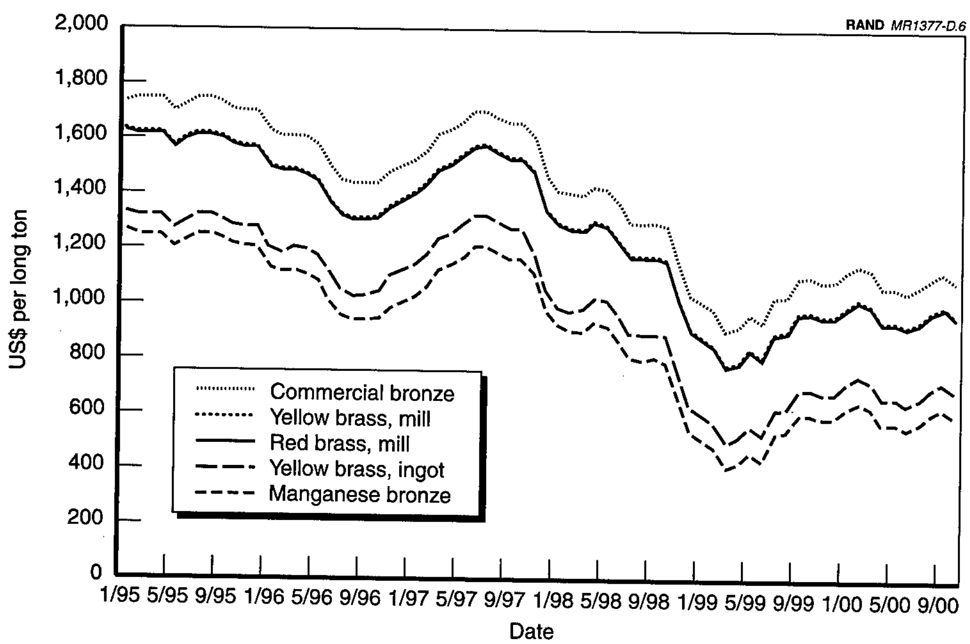

Figure D.6—Average Monthly U.S. Prices for Copper Alloy Scrap

per nickel heat exchangers. The average monthly price for brass and bronze scrap is shown in Figure D.6.[6]

Because the recovery fractions of copper and copper alloys are uncertain, the average of the copper and copper alloy prices for October 2000 was used, resulting in a value of $972 in current U.S. dollars per long ton.

For lead scrap, the primary metal price has been very volatile over the past five years. However, the price for scrap lead FOB to mill or dealer yard has varied little. We selected the October 2000 price of $213 in current U.S. dollars per long ton.

[6]Yellow brass, not used heavily in many ships because it deteriorates in seawater, is not considered in the average values used in the model.

COST-REVENUE SPREADSHEET MODEL

To support our calculations, we built a simple spreadsheet model in Microsoft Excel. This model allows quick summing of costs and revenues associated with the different ship disposal options.

The spreadsheet tracks the various ship types so that estimates of the cost of each disposal option will reflect the actual composition of the fleet rather than a generic fleet of "ships." Ships are classified as surface combatants, carriers, amphibians, auxiliaries, nonnuclear submarines, minesweepers, and others. The inputs to the model are as follows.

NAVY AND MARAD STORAGE COST FACTORS

The inputs for the Navy and MARAD cost factors are separate but they reflect similar categories. The spreadsheet provides inputs for the following: annual operations and maintenance funding per ship designated for scrap, operations and maintenance funding per ship designated for long-term storage, one-time costs for cathodic protection/dehumidifying (CP/DH) installation, a dry dock interval and dry dock cost per ship, an operations and maintenance aging cost factor, and, for MARAD ships, a follow-on dry dock cost per ship.

TOWING COST FACTORS

Towing cost inputs include towing costs in dollars per mile, the cost to outfit a ship for towing, the average distance to a recycling yard, and the average distance to a reefing site.

SHIP DISMANTLING COST FACTORS

Inputs include the cost to prepare a ship for dismantling represented as dollars per ton, dismantling costs per ship type represented as dollars per ton, number of shipbreaking sites, length of the dismantling effort in years, and an im-

provement factor to account for the learning and eventual efficiencies that result from experience.

SHIP REEFING PREPARATION COST FACTORS

These cost factors are organized much like those associated with dismantling. Inputs include the cost to prepare a ship for reefing represented as dollars per ton, preparation costs per ship type represented as dollars per ton, number of preparation sites, length of the reefing effort in years, and an improvement factor to account for the learning and eventual efficiencies that result from experience.

REVENUE OFFSETS

The spreadsheet makes use of two further inputs: scrap metal prices by type (e.g., copper, steel) represented as dollars per long ton or pound, and scrap metal recovery factors for calculating how much of each species will be recovered for ships of each given type.

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